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FACTORS INFLUENCING THE ABSCISSION OF FLOWERS AND PARTIALLY DEVELOPED FRUITS OF THE APPLE (PYRUS MALUS L.)

A THESIS

PRESENTED TO
THE FACULTY OF THE GRADUATE SCHOOL OF CORNELL UNIVERSITY
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY
ARTHUR JOHN HEINICKE

PUBLISHED AS CORNELL UNIVERSITY AGRICULTURAL
EXPERIMENT STATION BULLETIN 393, JULY, 1917

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FACTORS INFLUENCING THE ABSCISSION OF FLOWERS AND PARTIALLY DEVELOPED FRUITS OF THE APPLE (PYRUS MALUS L.)[1]

ARTHUR J. HEINICKE

Observations have shown that normally less than ten per cent of the apple blossoms which open in spring produce fruit. Many of the flowers are lost a few days after the petals fall, and a large number of the partially developed fruits are thrown off during the next few weeks. A rather conspicuous drop, commonly called the *June drop*, occurs in June and July, when the fruits are from one to three centimeters in diameter.

This June drop may or may not be beneficial to the fruit grower. If more than five to ten per cent of the flowers on a tree producing a heavy bloom set fruit, a large quantity of apples must be removed by hand so that the remaining specimens can attain a desirable size and color. On the other hand, apple trees frequently produce an abundance of flowers but little or no fruit is harvested from them, practically all the apples being lost during the June drop or before.

Diseases, insects, and unfavorable weather are often held acco ntable for the heavy loss of flowers and partially developed fruits. In unsprayed orchards the flowers and fruits that have fallen from the trees often show injury by scab and codling moth. Heavy losses sometimes result from the effects of winter injury, frost, wind, and hail. But in many cases the drop occurs even in the absence of such destructive agents.

The failure of a large proportion of apple blossoms to set, and the heavy loss of partially developed fruits during the June drop, are frequently associated with poor pollination and lack of fertilization. The fact that a large proportion of the apples that fall generally have fewer seeds to the fruit than those that remain on the tree, indicates that the development of seeds is an important factor in fruit setting. Nevertheless, many flowers set fruit even tho they are poorly pollinated, and many fruits remain on the tree even tho they have relatively few seeds.

Obviously, then, there are other factors, aside from the destructive agents previously mentioned, and in addition to poor pollination and lack of fertilization, which influence the abscission of flowers and partially developed fruits of the apple. To study such factors was the object of a

[1] Also presented to the Faculty of the Graduate School of Cornell University, September, 1916, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

AUTHOR'S ACKNOWLEDGMENT. The writer wishes to acknowledge his indebtedness to Professor W. H. Chandler, who proposed the problem and who gave many helpful suggestions during the course of the investigations.

series of observations and experiments that have been in progress during the past three seasons. The results obtained during this time are presented in this bulletin.

SURVEY OF LITERATURE

In early times the success or failure of the fruit crop was attributed largely to weather conditions. This may be inferred from folklore similar to that recorded by Bull (1878).[2] The conditions mentioned in the following quotation, for example, involve an early spring and rather dry weather:

> March dust on an apple leaf,
> Brings all kinds of fruit to grief.

In another quotation, emphasis is placed on the time of blooming, which likewise involves weather conditions:

> If the apple tree blossoms in March,
> For barrels of cider you need not *sarch*,
> But if the apple tree blossoms in May,
> You can eat apple dumplings every day.

The chances of having cold, windy, cloudy, and rainy weather during blooming time would be greater in March than in May. Besides, the weather conditions immediately after fertilization of the flowers would probably be more favorable for fruit development during a late spring than during an early one.

The following extracts from Langley (1729 a) are interesting since he attempts to explain the observed phenomenon on a physiological basis. Referring to the fact that "there are many excellent Kinds of Fruits which produce great Plenty of Blossoms, and but very little Fruit," Langley writes:

> This Sterility is caused by the too great Abundance of Wood, which, when 'tis cover'd over with its beautiful Blossoms, requires a much greater Quantity of Nourishment than the Roots are at that Time able to communicate, and thereby, for want of proper Nourishment, the Embryo Fruits are starved, and more especially when the Soil and Spring are both dry, their Perspirations [transpirations] being then greatest; and if Easterly Winds happen to blow at that Time, their very drying exhaling Nature, is a further Help to the Destruction of the Fruit.

This author also observed that some peaches in which the blossoms open before the leaves, such as Old Newington, have a tendency to produce smaller crops of fruit than such varieties as Albemarle and Catherine, which produce leaves with their blossoms. He believed that the leaves "strongly attract Nourishment from the Roots to the Blossoms."

Referring to the June drop, Langley (1729 b) writes:

> Now [from May 20 to June 20]..... 'tis always seen that great Quantity of Fruit drops, altho' largely grown. Of this all our late Authors on

[2] Dates in parenthesis refer to bibliography, pages 112 to 114.

Gardening take Notice, and therefore advise, that the thinning of Fruits be omitted, until it appears that this great Fall is over. . . . . 'Tis very easy to conceive, that if very dry Weather exhales away that Moisture which is necessary for those Formations [the internal parts of the fruit, such as the kernels, stones, and the like], the Work will be imperfect, and consequently the Fruits must perish.

Several experiments to prevent the drop were attempted during Langley's time. The most successful method found was "to preserve them [the trees] from the very hot Sun, from ten in the Morning until two or three in the Afternoon" by means of a sail cloth. Langley, having tried this method, recommends it to "the Practice of the Diligent and Curious." He adds, "'Tis very serviceable to give the Trees a gentle Refreshing of Water, at the Time you begin to screen them from the Sun, which they will freely imbibe, and [which] very much strengthens Nature in her Productions."

At the present time the weather is still in many cases held accountable for the failure of blossoms to set fruit. Osterwalder (1907 a), for example, cites the causes which the peasants of Switzerland hold accountable for the wholesale dropping of fruit. Among others, he mentions the "dew rain" of the early morning, which occurs during blooming time and subsequently; the strong mountain winds which prevail shortly after blooming time; and the presence of "honeydew" on the leaves. This honeydew, now known to be the result of aphid work, was formerly associated with local climatic conditions.

Hedrick (1908) has given renewed emphasis to the importance of weather in fruit setting. He is of the opinion that unfavorable weather during blossoming time is the predominating factor in the loss of fruit crops. Besides mentioning the direct and obvious damage done by frost, hail, wind, and the like, to buds, flowers, and fruits, this author points out that rain, cloudiness, wind, and low temperatures during blossoming time offer unfavorable conditions for pollination and subsequent fertilization.

Waite (1894) observed that many varieties of apples and pears are self-sterile. Fruits resulting from cross-pollination were found to be larger and finer specimens than those resulting from self-pollination. The former contained large, plump seeds, and the latter, small and flattened seeds. It was also noted that the ability of a tree to set fruit, either with its own pollen or with that from another tree, was affected by its state of nutrition and its general environment.

Since Waite's work, the need of cross-pollination to insure a set of fruit has received considerable attention. While most of the writers or workers on this question — among whom may be mentioned Hansen (1894), Beach (1895), Budd (1896), Waugh (1896, 1901), Munson (1899),

Fletcher (1900), Goff (1901), Green (1902), Close (1903), Lewis and Vincent (1909), Bellair (1910), and Gardner (1913) — recognize, as does Waite, that there are other factors, aside from self-sterility, which cause the falling of blossoms and immature fruits, all of them seem inclined to attach special importance to the necessity of cross-pollination for many varieties of fruits. It is pointed out that the structure of the flowers in many cases is such as to inhibit self-pollination, whereas many flowers have special modifications that seem to favor cross-pollination. The influence of such factors as weather, and the like, which favor or prevent cross-pollination, are emphasized.

Other workers, the chief among these being Müller-Thurgau (1898, 1908) and Ewert (1906, 1907, 1910), while not ignoring the question of pollination, have directed special attention to the importance of nutrition as a factor in fruit setting.

Müller-Thurgau has done most of his work with the grape. He finds (1898) that certain varieties can develop fruits without having the flowers fertilized. If, however, the blossoms of such varieties are emasculated and cross-pollination is prevented by inclosing the flowers in sacks, fruits do not develop. This author holds that the entrance of the pollen tube into the pistil may exert sufficient stimulus to initiate fruit development, even tho fertilization does not occur. The stimulus is believed to be one of a chemical nature which exerts an influence similar to that exerted by fertilization, tho less far-reaching. This influence is not confined to the single berry that has been pollinated or fertilized, but other berries on the same bunch are affected in such a way that they may develop even without the entrance of a pollen tube.

Girdling the cane eight days before the flowers opened prevented the shedding of berries, while similar canes not treated lost their immature fruit. The berries produced were seedless, hence fertilization had not occurred. Müller-Thurgau believes that the ringing afforded better conditions of nourishment for the flowers, so that the pollen tube could germinate and enter the stigma and style. In a subsequent paper (1908) this author records cases in which he obtained a set of seedless grapes even without the stimulus of pollination.

Müller-Thurgau noticed also that the berries on that part of the vine above the girdle were heavier than those borne below the girdle. The latter usually contained some seeds while the former were often seedless. Berries on vigorous shoots were larger than those on relatively weak growth even tho the weak canes were girdled. On a given cane, the berries with seeds were larger than those without seeds, and, furthermore, the size of the fruit was found to be proportional to the number of seeds contained in it.

Vines growing in the open but protected from cold rains lost their fruit, as did plants exposed to the rain. Müller-Thurgau states that rain during warm weather at blooming time does not necessarily have a detrimental effect on subsequent fruiting. He is of the opinion that the falling of blossoms and immature berries of the grape is due to an inadequate supply of easily respirable food. Pollination may overcome a temporary shortage by affording a stimulating influence; fertilization is even more effective in causing the set on weak vines or during unfavorable conditions for assimilation and translocation of food. The conditions that obtain for the grape are said to hold for the apple and the pear as well.

Ewert (1906, 1907, 1909) has given considerable attention to the development of seedless fruits. He believes that the development of such parthenocarpic fruits is possible if an abundance of food is available — such a supply, for example, as would accumulate if the downward movement of sap were inhibited. Ewert assumes that fruit formation on a tree occurs under competition for organic food. Such food, he thinks, has a greater tendency to flow to those fruits that contain seeds, which in turn are the result of cross-pollination. Consequently, seedless fruits developing on the same tree with fruits containing seeds are handicapped, and if the food supply proves inadequate such fruits will eventually fall off.

Inclosing the flower spurs in sacks is said by Ewert to bring about unfavorable conditions for nutrition. Fruits developed on such inclosed spurs, which must be self-pollinated if pollinated at all and which consequently produce very poor seeds, are therefore handicapped in their development. If the ability of a tree to set fruit without pollination is to be determined, it therefore becomes necessary to prevent pollination on all flowers and not merely on a few. When this precaution was observed Ewert obtained seedless fruits which were as large as normal specimens. He found, however, that the same variety was less likely to set parthenocarpically when some of the flowers on the tree were exposed to cross-pollination.

Ewert found also that the dicogamy of the flowers is not always associated with self-sterility, nor is the absence of this condition, which would favor self-pollination, strictly associated with self-fertility. He believes that the question of the need for cross-pollination in fruit setting has been overemphasized. He is of the opinion that cold, rainy weather at blooming time is unfavorable to the setting of fruit, not so much because it hinders fertilization as because such conditions are generally harmful to the development of the young fruit.

Osterwalder (1907 a, 1909) has also given the question of premature drop considerable attention. His studies of the seeds of fruits that remain

on the tree, and of those that are shed several weeks after blooming time, have shown that fertilized as well as unfertilized fruits drop. Osterwalder studied also the transpiration by the petals of the flowers. The amount of water lost in this way was found to be much less than that given off by a similar area of leaf surface. He believes that wilting of the floral parts is more likely to result from the loss of water thru the leaves than thru the petals. He holds that fruitfulness depends on nutrient conditions, on the number of fertilized fruits, and on the tendency of the variety to develop fruits parthenocarpically.

Insects and diseases, chiefly codling moth and scab, are often mentioned in literature as causing heavy drops of blossoms and immature fruit (Bailey 1895, Reddick 1912, Wallace 1913). Too rapid vegetative growth, especially of young trees, is sometimes cited as unfavorable to fruit setting (Waite, 1894). A number of other general causes, such as poor soil, plowing during blooming time (Gould, 1915), drought, and the like, are occasionally held accountable for crop failure after blossoms have been produced.

MATERIAL USED IN THESE EXPERIMENTS

The observations and experiments recorded in these pages were made during the course of three summers, 1914 to 1916 inclusive. For the most part the work was done at the experiment station orchard at Ithaca, New York, but observations on a few outlying orchards in western New York were also made. Unless otherwise mentioned, the trees under observation were between forty and fifty years old. About seven years ago these trees were pruned severely, and since that time they have received ordinary care — that is, cultivation, pruning, and thoro spraying.

In this paper the natural drop only is considered, not the drop caused by such external agents as frost, insects, and diseases. In a well-sprayed orchard the drop resulting from scab and from codling moth is practically negligible. Examination of several hundred flowers and small fruits collected from sheets suspended under the trees in the station orchard at Ithaca in the spring of 1916, showed that only about one per cent were affected by scab. In western New York, however, the unfavorable weather did not permit the growers to spray effectively that spring, and, as a result, scab infection on the stems of flowers and young fruits caused a heavy drop. Cases of a similar nature have been reported previously (Bailey 1895, Reddick 1912, Wallace 1913).

MAGNITUDE OF THE FIRST AND OF THE JUNE DROP

Before any experimental work was undertaken, a detailed survey was made of the extent and distribution of the first drop and of the June

drop. By *first drop* is meant the loss of flowers and of very slightly developed fruits that occurs within from one to three or four weeks after the petals fall. In the majority of these drops, the ovary and surrounding tissue has not developed beyond the flower stage. In a relatively few cases, the young fruits have attained a diameter of from one-half to one centimeter before they fall.

Flowers developing into fruits after the first drop

The extent of the first drop is indicated by the data given in table 1. The figures are based on a consideration of all flower-bearing spurs found

FIG. 1. VIGOROUS SPUR, PRODUCING FRUIT AND LATERAL GROWTH

Lateral shoots are shown at A and B. The spur growth made since spring is shown at C. The leaves on this growth are the bud leaves. The large scar at E is from the stem of an apple that fell at the June drop; the small scars at D are flower-stem scars. A part of the preceding year's growth is shown at F. (½ natural size)

on a number of different branches from one or more trees of each variety. Normal branches from five to ten years old were chosen. They varied in length between one meter and one and a half meters. The total number of flowers was determined by counting the number of flower-stem scars on the ends of the spurs and the number of fruits remaining on the spurs (fig. 1).

TABLE 1. PERCENTAGE OF FLOWERS DEVELOPING INTO FRUITS AFTER THE FIRST DROP

Variety	Total number of flowers	Number set	Percentage set	Percentage lost
Maiden Blush	271	166	61.2	38.8
Westfield	478	270	56.5	43.5
Fallawater	268	47	17.5	82.5
Baldwin	656	110	16.8	83.2
Tompkins King	1,563	335	21.4	78.6
Rhode Island	840	183	21.8	78.2

From two-fifths to four-fifths of the flowers are lost during the early drop. The varieties given in the table fall into two groups, depending on the number of flowers lost. One group, represented by Maiden Blush and Westfield, lost only half as many as did the other group. All varieties were growing in the same orchard and they bloomed during the same time; consequently they had equal chances of being cross-pollinated. Can the variations noted be due to a tendency toward self-fertility in the first group? Subsequent data may throw some light on this question.

Spurs setting fruit after the first drop

From a practical standpoint, it is interesting to note the percentage of flower-bearing spurs that set fruit. Such data are presented in table 2:

TABLE 2. PERCENTAGE OF FLOWER-BEARING SPURS RETAINING FRUIT AFTER THE FIRST DROP

Variety	Number of spurs with flowers	Number with fruit	Percentage with fruit	Percentage without fruit
Maiden Blush	157	154	98.1	1.9
Westfield	89	84	94.4	5.6
Fallawater	116	79	68.1	31.9
Baldwin	302	183	60.6	39.4
Tompkins King	478	307	64.2	35.8
Rhode Island	534	296	55.4	44.6

The figures are based on counts of all flower-bearing spurs found on a number of different branches taken from one or more trees of each variety. The branches used were similar to those already described.

It is seen from the table that in some varieties practically all spurs set fruit, while in others almost half of the flower-bearing spurs fail to set fruit.

Variations in percentage of spurs setting fruit after the first drop.— The variations found in different branches, in the percentage of spurs that set fruit after the first drop, are shown in table 3. Most of the branches were about one and one-half to two centimeters in diameter at the base, and the wood was from one to at least five years old. Only healthy and apparently normal branches were considered.

TABLE 3. VARIATIONS IN THE PERCENTAGE OF FLOWER-BEARING SPURS THAT SET FRUIT AFTER THE FIRST DROP

Variety and tree	Branch	Total number of spurs	Number setting fruit	Per-centage setting fruit
Fallawater, B 2	1	26	19	73.1
	2	36	22	61.1
	3	27	18	66.7
	4	27	20	74.1
Baldwin, B 8	1	24	21	87.5
Baldwin, E 7	1	16	10	62.5
	2	16	9	56.2
	3	20	12	60.0
	4	13	9	69.2
	5	19	8	42.1
	6	12	6	50.0
	7	17	12	70.6
Baldwin, E 10	1	6	4	66.7
	2	9	6	66.7
	3	14	9	64.3
	4	24	17	70.8
	5	23	15	65.2
	6	20	13	65.0
	7	16	11	68.8
	8	25	13	52.0
	9	18	14	77.8
	10	18	9	50.0
	11	16	6	37.5
Westfield	1	60	57	95.0
	2	29	27	93.1
Maiden Blush, A 8	1	69	69	100.0
	2	29	29	100.0
	3	12	12	100.0
	4	28	28	100.0
	5	19	16	84.2

TABLE 3 (*concluded*)

Variety and tree	Branch	Total number of spurs	Number setting fruit	Percentage setting fruit
Tompkins King, C 2	1	33	24	72.7
	2	19	18	94.7
	3	29	21	72.4
	4	10	9	90.0
	5	14	10	71.4
	6	15	10	66.7
	7	36	26	72.2
	8	76	52	68.4
	9	20	11	55.0
	10	23	10	43.5
	11	20	9	45.0
	12	34	14	41.2
	13	25	11	44.0
Tompkins King, C 3	1	35	31	88.6
	2	28	16	57.1
	3	18	9	50.0
	4	33	16	48.5
	5	10	10	100.0
Rhode Island, B 5	1	21	9	42.8
	2	47	22	46.8
	3	100	38	38.0
	4	51	32	62.7
	5	55	31	56.4
Rhode Island, B 3	1	47	39	83.0
	2	49	35	71.4
	3	80	42	52.5
	4	60	28	46.7
	5	24	20	83.3

The figures for the individual branches of a given tree vary considerably. Casual observations have shown that these differences cannot be explained by the location, angle, or exposure of the branch on the tree, since the differences are sometimes found in similarly located branches. For example, in Rhode Island B 5, branches 1, 2, and 3 all came from the top of the tree; in Tompkins King C 2, branches 1 and 5 were from the south side of the tree, branches 2, 3, and 4 were from the north side, branches 6, 7, and 8 arose from the same parent limb on the southwest side of the tree, branches 9 and 10 were growing upward at an angle of 45°, and branches 11, 12, and 13 were drooping. Figures presented later (page 58) afford a probable explanation for the differences noted.

Flowers developing into fruits after the June drop

Totals of flowers on many limbs.— Branches were examined in the latter part of July and in early August for the number of fruits set after the June

drop. Data based on all flower-bearing spurs found on various branches are given in table 4. The number of flowers originally borne on each spur

TABLE 4. PERCENTAGE OF FLOWERS DEVELOPING INTO FRUITS AFTER THE JUNE DROP

Variety	Total number of flowers	Number set	Percentage set	Percentage lost
Tompkins King	2,849	84	2.9	97.1
Baldwin	770	53	6.9	93.1

was obtained by counting the flower scars and the fruits on the spur. Approximately three to seven per cent of the total number of flowers finally developed into fruits.

Flowers falling at the first drop and at the June drop on fruit-bearing spurs.— The figures in table 5 show the relation between the first drop and the June drop. The data are based on a consideration of all fruit-setting spurs found on several branches from trees of each variety. They do not take into consideration the spurs that bore flowers but failed to set fruit. The first column of figures contains the total number of spurs, and the second contains the total number of flowers found on these spurs. Unless otherwise mentioned, the percentages are based on the original number of flowers.

TABLE 5. FIRST DROP AND JUNE DROP ON FRUIT-SETTING SPURS

Variety	Number of spurs	Number of flowers	Fruits falling at first drop		Fruits falling at June drop			Fruits finally setting	
			Number in drop	Percentage of drop	Number in drop	Percentage of drop (A)	Percentage of drop (B)	Number set	Percentage set
Westfield	47	281	7	2.5	227	80.8	82.8	47	16.7
Maiden Blush	54	281	90	32.0	126	44.8	66.0	65	23.1
Tompkins King	93	557	416	74.7	38	6.8	26.9	103	18.5
Fallawater	56	252	192	76.2	10	4.0	16.7	50	19.8
Rhode Island	30	154	116	75.3	8	5.2	21.1	30	19.5
Baldwin	46	258	203	78.7	9	3.5	16.4	46	17.8

(A) Percentage based on original number of flowers.
(B) Percentage based on number of fruits remaining after first drop, obtained by subtracting figures in fourth column from those in third column.

The figures indicate that the June drop is relatively small when the first drop is large. On the other hand, if a large proportion of the flowers begin to form fruits, the June drop will be heavy. Approximately twenty per cent of the flowers on fruit-setting spurs finally develop, which means one fruit to the spur. The variety Maiden Blush has a tendency to develop more than one fruit to the spur. The percentage is somewhat lower than

twenty in Westfield, because this variety averages higher than five flowers to the spur. The percentage of flowers which finally set, as given in table 5, is obviously too high if all flower-bearing spurs are considered.

Spurs setting fruit after the June drop

Consideration of spurs from many limbs.— The percentage of flower-bearing spurs that retain fruits after the June drop is given in table 6. These data were obtained during the latter part of July and the early part of August. The figures are based on a consideration of all spurs found on many branches of each variety.

TABLE 6. PERCENTAGE OF FLOWER-BEARING SPURS RETAINING FRUIT AFTER THE JUNE DROP

Variety	Number of spurs with flowers	Number with fruit	Per-centage with fruit	Per-centage without fruit
Baldwin	1,945	630	32.4	67.6
Tompkins King	368	68	18.5	81.5
Rhode Island	428	73	17.1	82.9

Only about one-sixth to one-third of the flower-bearing spurs become fruit-setting spurs, as indicated by these data.

Variations in percentage of spurs setting fruit after the June drop.— The percentages of fruit-bearing spurs on individual twigs of a number of varieties are given in table 7. Notes concerning the source of the individual twigs were obtained in some cases. These indicate that the angles

TABLE 7. VARIATIONS IN THE PERCENTAGE OF FLOWER-BEARING SPURS THAT SET FRUIT AFTER THE JUNE DROP (1915)

Variety and tree	Branch	Total number of spurs	Number setting fruit	Per-centage setting fruit
Baldwin, B 8	1	15	7	46.7
	2	28	9	32.1
	3	11	6	54.5
	4	10	6	60.0
	5	30	5	16.7
	6	188	41	21.8
Baldwin, E 7	1	18	10	55.5
	2	19	11	57.9
	3	8	6	75.0
	4	23	12	52.2
	5	10	7	70.0

TABLE 7 (*concluded*)

Variety and tree	Branch	Total number of spurs	Number setting fruit	Percentage setting fruit
Baldwin, E 7 (*continued*)	6	215	82	38.1
	7	345	55	15.9
	8	145	30	20.7
	9	281	69	24.5
	10	385	175	45.4
Baldwin, E 10	1	25	14	56.0
	2	6	4	66.7
	3	9	6	66.7
	4	14	6	42.9
	5	24	13	54.2
	6	23	7	30.4
	7	20	9	45.0
	8	16	9	56.3
	9	25	8	32.0
	10	18	10	55.5
	11	18	9	50.0
	12	16	4	25.0
Tompkins King, C 1	1	146	21	14.4
Tompkins King, C 2	1	42	7	16.7
	2	31	2	6.5
	3	25	3	12.0
Tompkins King, C 3	1	35	10	28.6
	2	28	9	32.1
	3	18	4	22.2
	4	33	9	27.3
	5	10	3	30.0
Rhode Island, B 5	1	27	1	3.7
	2	23	1	4.3
	3	18	2	11.1
	4	17	1	5.9
	5	35	1	2.9
Rhode Island, B 3	1	88	30	34.1
	2	127	21	16.5
	3	6	1	16.7
	4	34	5	14.7
	5	53	10	18.9

at which the branches grow and their location on different parts of the tree cannot be held accountable, in themselves, for the variations found. For example, in Baldwin B 8, branches 1 and 3 were growing in an upright position, and branches 2 and 4, found on the same side of the tree, were drooping; in Baldwin E 7, branches 1 to 4 were obtained from the top of the tree, and branches 5 to 10 from limbs close to the ground.

RELATION BETWEEN AMOUNT OF BLOOM AND SET OF FRUIT

In the spring of 1916 most of the mature trees in the station orchard at Ithaca produced a heavy bloom. Individual limbs on many of the trees, however, bore relatively few flowers. A number of such limbs, with a light bloom, were labeled. Corresponding limbs with a heavy bloom, but otherwise like the former — having a similar exposure, and arising from the same parent limb — were also labeled. After the June drop, the total number of flower-bearing spurs on each limb was obtained, together with the number of spurs that had set fruit. The data from some of the branches are recorded in table 8:

TABLE 8. PERCENTAGE OF SPURS SETTING FRUIT ON LIMBS WITH HEAVY BLOOM AND ON THOSE WITH LIGHT BLOOM

Variety	Limbs with light bloom			Limbs with heavy bloom		
	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
Baldwin, tree 1	52	40	76.9	116	18	15.5
Baldwin, tree 2	47	38	80.8	76	39	51.3
Fallawater	21	10	47.6	255	21	8.2
Westfield	25	19	76.0	250	20	8.0
Total	145	107	73.8	697	98	14.1

A larger percentage of spurs set fruit in the limbs with the relatively light bloom. This fact is easily apparent on inspection, even without accurate counts. Hence, only a relatively few limbs were removed from the trees to obtain records, the remainder being used for other purposes. An explanation for the results obtained is afforded by subsequent observations.

SET OF FRUIT ON LIMBS WITH LARGE LEAVES AND ON LIMBS WITH SMALL LEAVES

It is not uncommon to find individual limbs with leaves noticeably smaller than those on the remaining limbs of the same tree. In the spring of 1916, such small-leaved limbs which had produced a heavy bloom were labeled. Limbs with normal leaves, but otherwise similar, were likewise labeled. The percentage of flower-bearing spurs that set fruit was determined for each group of branches. Data of several of the many limbs labeled are contained in table 9:

TABLE 9. PERCENTAGE OF SPURS SETTING FRUIT ON WEAK AND ON VIGOROUS LIMBS

Variety	Vigorous limbs with large leaves			Weak limbs with small leaves		
	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
Unknown	164	94	57.3	219	33	15.1
Tompkins King	223	67	30.0	207	34	16.4
Total	387	161	41.6	426	67	15.7

The percentage of flower-bearing spurs that set fruit was greater on the branches with large leaves than on those with small leaves. The same condition prevailed on the other limbs that had been labeled, as was determined by careful inspection. These results can probably be explained on the basis of data presented later in these pages.

SET OF FRUIT AS INFLUENCED BY THE LOCATION OF THE SPUR ON THE TWIG GROWTH OF DIFFERENT YEARS

Observations were made to determine whether flower-bearing spurs arising from wood of different ages would be more likely to set fruit in some cases than in others. Data regarding this point are given in tables 10, 11, 12, and 13. These figures were obtained during the summer

TABLE 10. PERCENTAGE OF FLOWERS DEVELOPING INTO FRUITS AFTER THE FIRST DROP, ON SPURS ARISING FROM WOOD OF DIFFERENT AGES

Year's wood	Tompkins King, tree 1			Tompkins King, tree 2		
	Number of flowers	Number set	Percentage set	Number of flowers	Number set	Percentage set
1914	65	11	16.9	25	3	12.0
1913	379	97	25.6	101	34	33.7
1912	129	44	34.1	85	12	14.1

of 1915, hence the spurs on 1914 twig growth came from lateral buds. Ordinarily, few lateral buds form blossoms in New York State, and such formation may be ascribed to the unusually favorable conditions for fruit-bud formation which prevailed during 1914 — a wet spring followed

by a dry, sunny season. Comparatively few of the flowers arising from such buds set fruit, as may be seen from the figures. Other observations indicate that the length of the 1914 wood influenced the setting ability of the flowers arising from the lateral buds. In a number of cases in which the growth was twenty-five centimeters and the terminal bud produced a flower, few, if any, lateral buds set. When the growth was less vigorous, it was not uncommon to find fruits produced on the lateral buds.

TABLE 11. SET ON SPURS ARISING FROM WOOD OF DIFFERENT AGES

Year's wood	Tompkins King, tree 1			Tompkins King, tree 2			Baldwin			Rhode Island		
	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
1914	5	3	60.0	15	7	46.7	12	5	41.7	16	4	25.0
1913	36	25	69.4	70	54	68.4	86	63	73.3	10	5	50.0
1912	16	7	43.8	25	20	80.0	34	24	70.6	....	....	.....
1911	11	4	36.4	....	....	.....	32	14	43.8	....	....	.....
1910	31	16	51.6	....	....	.....	14	5	35.7	....	....	.....

TABLE 12. PERCENTAGE OF FLOWERS DEVELOPING INTO FRUITS AFTER THE JUNE DROP, ON SPURS ARISING FROM WOOD OF DIFFERENT AGES

Year's wood	Tompkins King, tree 1			Tompkins King, tree 2		
	Number of flowers	Number set	Percentage set	Number of flowers	Number set	Percentage set
1914	65	3	4.6	25	3	12.0
1913	379	46	12.1	191	34	17.8
1912	129	29	22.5	85	12	14.1
1911	.....	.....	.....	65	4	6.2
1910	.....	.....	.....	169	27	16.0
1909	.....	.....	.....	96	12	12.5

Such observations can be interpreted on the basis of nutrition, that is, an adequate supply of stored food which is readily available in spring, as well as a sufficient supply of water. So long as active growth continues, the assimilate is probably translocated to the growing parts; little is left for storage and fruit-bud formation in the lateral buds. After growth finally ceases on long twigs, the time remaining for active assimilation is inadequate for abundant storage. On the other hand, short twigs stop elongating much sooner; consequently, the lateral buds on short twigs can store the food which is utilized for continued length growth

TABLE 13. SET ON SPURS ARISING FROM WOOD OF DIFFERENT AGES

Year's wood	Tompkins King, tree 1			Tompkins King, tree 2			Tompkins King, tree 3			Baldwin, tree 1			Baldwin, tree 2		
	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
1914	15	3	20.0	5	1	20.0	11	3	27.3	20	8	40.0	12	3	25.0
1913	79	39	49.4	36	7	19.4	49	23	46.9	89	47	52.8	273	84	30.8
1912	25	17	68.0	16	4	25.0	16	7	43.8	36	17	47.2	. . .	. . .	. . . . .
1911	. . . .	. . . .	. . . .	. . .	. . .	. . . .	13	5	38.5	34	10	29.4	. . .	. . .	. . . . .

on long twigs. No analyses are available to show that such a condition actually exists.

In several cases, the spurs arising from 1913 twig growth set more fruit than did spurs arising from older wood. In other cases, however, spurs on older twigs were more fruitful than those on younger growth. This fact suggests that the ability of a bud to develop into a fruit-setting spur is determined to some extent during the year when it is formed in the axil of a leaf. It should be mentioned, in this connection, that many limbs have no flower-bearing spurs on a given year's growth, whereas such spurs are borne on younger and on older wood of the same limb. Then, too, the proportion of buds that develop into fruiting spurs varies with the different year's growth on the same branch.

Apparently the age of the spur alone, at least from the second to the fourth or the fifth year, has little influence on its fruitfulness. Spurs arising from wood several meters from the periphery of the tree would generally be in a less desirable position so far as exposure to light and free circulation of air are concerned. This condition would probably have an unfavorable influence on the nutrition of the fruit bud.

SET OF FRUIT ON SPURS FORMED ON DIFFERENT PARTS OF A GIVEN YEAR'S GROWTH

The vigor of the individual buds found on the twig growth of a given year varies considerably. This can be determined by observing the fate of the buds the year after they have been formed. In most of the varieties, buds near the beginning, and in many cases those just before the end, of a year's growth remain dormant (Koopmann, 1896). If a year's growth happens to be from thirty to forty centimeters, a third zone of weak buds may be found near the center of that particular year's growth. The transition from dormant buds to those that produce strong spurs, or even short twigs, is usually, but not always, a gradual one. The strongest spurs are generally found just before the terminal zone of dormant buds, and before the middle zone if there is one. The leaves in the zones bearing weak buds will usually be the first to turn yellow and fall off if the twigs are removed from the tree and placed in beakers containing water. Such leaves likewise are the first to be shed in the autumn.

Just what causes these variations in bud vigor is not definitely known. They are found even in upright twigs growing at the top of the tree, where light conditions for the different buds are approximately the same. The nutrient supply available at the time of formation of the individual bud may determine its vigor. It is probable that the water supply from

the soil, the temperature, the humidity, cloudiness, and other environmental conditions, have marked influence on the nutrition.

In the summer of 1914, the fruit borne on spurs arising from 1912 or 1913 wood was found near the end of the season's growth in most cases. The percentage of flower-bearing spurs that set fruit in the terminal parts of a given year's growth, as compared to the set on the spurs in the lower halves of the same twigs, is shown in table 14. It is seen

TABLE 14. SET OF FRUIT ON SPURS FORMED ON DIFFERENT PARTS OF A GIVEN YEAR'S GROWTH

Variety	Spurs in upper half of year's growth			Spurs in lower half of year's growth		
	Number of spurs	Percentage set after first drop	Percentage set after June drop	Number of spurs	Percentage set after first drop	Percentage set after June drop
Baldwin.....	136	64.3	50.0	90	53.2	40.0
Tompkins King.	47	63.8	34.0	24	45.8	12.5

that there are fewer flower-bearing spurs in the basal half of the year's growth, and a smaller percentage of these basal spurs set fruit. The results would probably have been more striking if only the relatively short twigs had been considered. The long twigs, as has been mentioned, usually show a middle zone of weak or dormant buds, which are generally preceded by fruit-setting spurs. In such twigs, fruit-setting spurs would be found in the basal half of the year's growth.

RELATION BETWEEN NUMBER OF FLOWERS TO THE SPUR, AND ABILITY OF THE SPUR TO SET FRUIT

The number of flowers on an apple spur varies from two to seven. Casual observations seemed to indicate that there is a relation between the number of flowers produced by the spur and its ability to bear fruit. Consequently, a more careful study of this question was undertaken.

Average number of flowers on spurs holding fruit for varying lengths of time

Records were made of the number of flowers borne on spurs that lost all fruit at the first drop, on those that held fruit until the June drop but not longer, and on those that finally set fruit. The data are recorded in table 15:

TABLE 15. AVERAGE NUMBER OF FLOWERS ON SPURS HOLDING FRUIT FOR VARYING LENGTHS OF TIME

Variety	Spurs losing all fruit at first drop			Spurs holding fruit until the June drop			Spurs finally setting fruit		
	Number of spurs	Number of flowers	Average number of flowers to the spur	Number of spurs	Number of flowers	Average number of flowers to the spur	Number of spurs	Number of flowers	Average number of flowers to the spur
Tompkins King	39	144	3.69	23	114	4.96	64	354	5.53
Tompkins King	52	257	4.94	37	216	5.84	35	204	5.83
Rhode Island	60	271	4.52	116	569	4.91	....	.....	.....
Westfield	....	.....	.....	47	221	4.70	35	211	6.03
All varieties	151	672	4.45	223	1,120	5.02	134	769	5.74

There seems to be a correlation between the number of flowers on a spur and the ability of the spur to hold fruit. Spurs that lose all flowers and fruits during the first drop have the smallest average number of flowers, and those that finally set have the largest average number of flowers.

Set of fruit on spurs with varying numbers of flowers

The spurs from several branches were grouped in lots based on the number of flowers borne. The percentage of spurs bearing fruit in each case is recorded in table 16:

TABLE 16. SET OF FRUIT ON SPURS WITH VARYING NUMBERS OF FLOWERS

Variety	Branch	Spurs with 4 flowers		Spurs with 5 flowers		Spurs with 6 flowers	
		Number of spurs	Percentage set	Number of spurs	Percentage set	Number of spurs	Percentage set
Baldwin	1	7	42.9	32	56.2	63	*65.1
	2	7	42.9	39	41.0	70	†48.1
Tompkins King	1	18	11.1	33	51.5	62	*70.9
	2	18	11.1	33	21.2	62	†33.9
Rhode Island	.....	30	50.0	103	70.9	26	*79.2

* After the first drop.
† After the June drop.

These data likewise show that the fruit-bearing ability of a spur is closely related to the number of flowers produced by the spur. The spurs having the greatest numbers of flowers show the highest percentage set.

Percentage of flowers developing into fruits on spurs producing varying numbers of flowers

In many cases the spurs bear more than one fruit. Do individual flowers on spurs producing six blossoms have to compete more for their

portion of food and water, than flowers on spurs producing a smaller number of blossoms? The data in table 17 contain an answer to this

TABLE 17. PERCENTAGE OF FLOWERS DEVELOPING INTO FRUITS ON SPURS WITH VARYING NUMBERS OF FLOWERS

Variety	Branch	Spurs with 4 flowers		Spurs with 5 flowers		Spurs with 6 flowers	
		Number of flowers	Percentage set	Number of flowers	Percentage set	Number of flowers	Percentage set
Westfield	.....	28	28.9	150	54.0	228	†57.0
Baldwin	1	28	10.4	195	82.0	420	*90.0
	2	60	56.7	80	60.0	102	*72.5
Maiden Blush	1	24	45.1	110	60.0	138	*71.0
	1	24	20.9	110	20.0	138	†23.2

*After the first drop.
†After the June drop.

question. The figures indicate that a higher percentage of flowers develop into fruits on spurs producing six flowers than on spurs producing four or five flowers.

RELATION BETWEEN LENGTH OF SPUR GROWTH MADE DURING PRECEDING SEASON, AND FRUITFULNESS OF THE SPUR

In 1915 it was observed that many of the fruits were borne on spurs which had elongated more than two centimeters during the previous season. This fact was first noted in studying the set on Mr. F. W. Cornwall's Baldwin orchard at Pultneyville, New York. All flower-bearing spurs found on large branches from several trees were placed in two groups. The first group contained spurs that had made a growth of two centimeters

TABLE 18. SET OF FRUIT IN 1915 ON SPURS MAKING DIFFERENT GROWTH LENGTHS DURING THE PRECEDING YEAR

Branch	Spurs making 2 centimeters growth or more during 1914			Spurs making less than 2 centimeters growth during 1914		
	Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
1	17	13	76.5	34	9	26.5
2	24	13	54.2	57	18	31.6
3	37	21	56.8	58	16	27.6
4	36	25	69.4	67	17	25.4
Total	114	72	63.2	216	60	27.8

or more during 1914 — the year preceding that in which fruit was borne; the second group contained spurs that had made less than two centimeters growth in the same period. The percentage of spurs setting fruit in each group is given in table 18.

In 1916 similar data were obtained at the station orchard at Ithaca. All spurs that had elongated one centimeter or more in 1915 were placed in one class, and those that had grown less than one centimeter were placed in another. The percentages of spurs that produced fruit are recorded in table 19. It is seen from the table that spurs which have elongated more than one centimeter during any one year are more likely to set fruit in the following year than are spurs that have made a weaker growth.[3]

TABLE 19. SET OF FRUIT IN 1916 ON SPURS MAKING DIFFERENT GROWTH LENGTHS DURING THE PRECEDING YEAR

Variety	Branch	Spurs making 1 centimeter growth or more during 1915			Spurs making less than 1 centimeter growth during 1915		
		Number of spurs	Number set	Percentage set	Number of spurs	Number set	Percentage set
Strawberry	1	434	138	31.8	721	118	16.4
	2	405	122	30.1	659	113	17.1
	3	237	88	37.1	445	51	11.5
	4	567	182	32.1	878	162	18.4
Total	.....	1,643	530	32.3	2,703	444	16.4
Baldwin	1	67	57	85.1	52	25	48.1
	2	75	36	48.0	59	14	23.7
	3	50	31	62.0	117	30	25.6
	4	44	22	50.0	68	14	20.6
	5	84	69	82.1	61	8	13.1
Total	.....	320	215	67.2	357	91	25.5
Tompkins King	1	80	40	50.0	63	18	28.6
	2	23	6	26.1	48	8	16.7
Total	.....	103	46	44.7	111	26	23.4
Grand total	.....	2,066	791	38.3	3,171	561	17.7

Casual observations during 1915 seemed to indicate that flowers produced in the terminal bud of twigs making more than approximately twenty centimeters length growth in 1914 did not set as well as did flowers on shorter twigs. In 1916, however, the same varieties were setting at the ends of long twigs.

[3] Yeager (1916), in a bulletin which was received here while this paper was being prepared for publication, likewise reports a correlation between the amount of growth that a spur makes in one year and its production in the following year.

RELATION BETWEEN WEIGHT OF THE FLOWER-BEARING SPUR AND ITS FRUITFULNESS

Most writers on topics relating to fruit setting agree that the vigor of the tree is a factor to be considered. It is generally assumed that excessive vegetative growth is opposed to fruit production. No definite figures, however, are available regarding the influence of the vigor of the individual spur on fruit bearing.

When the fruit bud opens in spring, a short spur is produced varying in length from 0.3 to 2 centimeters. This new growth bears leaves laterally and a cluster of flowers terminally. It seems safe to assume that this spur growth is made at the expense of stored food. The stored food is the result of photosynthetic activity during the previous year. The amount of this early spur growth with its leaves and flowers can therefore be taken as an index to vigor.

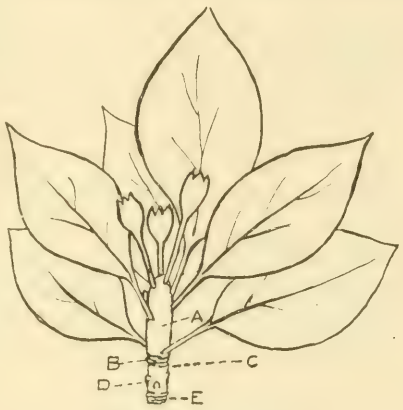

FIG. 2. PREPARATION OF SPUR PREVIOUS TO WEIGHING

The point C just below the ring of bud-scale scars, B, indicates the point at which the present year's growth, A, is cut from the preceding year's growth, D E. The fruits are removed before the spur is weighed. (Slightly reduced)

Weights of setting and of non-setting spurs

The relation of vigor to the fruit-setting ability of the tree was studied by ascertaining the weights of a large number of flower-bearing spurs. The spur growth of the current year was cut from the parent spur just at the base of the ring of bud scales protecting the bud from which the current year's growth came (fig. 2). The spurs were weighed in a turgid condition. The weights were taken early in the season, and any growth arising from a lateral bud on the current season's spur was removed before weighing.

All flower-bearing spurs found on a given limb were considered; the setting and the non-setting spurs were therefore produced on the same parent branch. The data given in table 20 are representative of the weights of setting and of non-setting spurs.

According to the table, the setting spurs on a given branch are heavier than the non-setting spurs on the same branch in all cases. It should be noted that the average weight of spurs may be greater on one branch than on others. More specific observations regarding this point are discussed later (page 73).

TABLE 20. WEIGHTS OF SETTING AND OF NON-SETTING FLOWER-BEARING SPURS

Variety	Branch	Setting spurs			Non-setting spurs		
		Number of spurs	Total weight (grams)	Average weight (grams)	Number of spurs	Total weight (grams)	Average weight (grams)
Baldwin	1	97	174.46	1.80	115	179.56	1.56
	2	66	210.50	3.19	47	91.87	1.95
	3	46	128.64	2.80	24	58.42	2.43
	4	139	383.60	2.76	112	162.40	1.45
	5	46	109.94	2.39	42	55.02	1.31
	6	42	105.00	2.50	16	24.96	1.56
Tompkins King	1	37	107.75	2.91	81	137.93	1.70
	2	34	59.50	1.75	175	134.75	0.77
Fallawater	.....	10	8.12	0.81	42	23.24	0.55
Rhode Island	.....	30	128.24	4.27	58	180.35	3.11
Westfield	.....	48	102.74	2.14	48	91.92	1.92
Total	.....	595	1,518.49	2.55	760	1,140.42	1.50

Set of fruit on spurs of different weights

The flower-bearing spurs from a Fallawater branch were classified, according to their weights, as heavy, medium, and light. The average weight of each lot is given in table 21, together with the percentage of spurs that produced fruit:

TABLE 21. SET OF FRUIT ON SPURS OF DIFFERENT WEIGHTS

Number of spurs	Average weight (grams)	Percentage with fruit
18	4.53	61.1
18	2.37	25.5
18	1.21	16.6

The heaviest spurs produced the most fruit, and the lightest produced the least. These data alone are insufficient to establish the relation between set of fruit and vigor of spur, but they lend additional support to the facts presented in tables 20 and 22.

Weights of spurs holding fruits for varying lengths of time

The weights of spurs that lost all fruit at the first drop, of those that held fruit until the June drop, and of those that held fruit after the

June drop, were obtained in the case of a large limb taken from a Baldwin tree in July, 1915. The scars on the spurs that had lost fruits during the June drop were easily distinguishable from the smaller scars of the flowers and fruits that had been lost earlier. The data are recorded in table 22:

TABLE 22. WEIGHTS OF SPURS HOLDING FRUITS FOR VARYING LENGTHS OF TIME

Time spur held fruit	Number of spurs	Total weight (grams)	Average weight (grams)
Until first drop	30	88.12	2.94
Until June drop	28	92.23	3.29
After June drop	30	128.23	4.27

The spurs that finally set fruit are heavier than the others. Those that hold fruit until the June drop weigh more than those that lose all fruit during the first few weeks.

Relation between weight, or vigor, of the fruit-bearing spur, and number of fruits borne by it

In several cases the fruit-bearing spurs from a given limb were divided into two lots. One lot consisted of spurs that produced one fruit, the other of spurs that produced two fruits. The average weight of each lot was obtained. The figures are recorded in table 23, and show that spurs bearing but one fruit are not so heavy as those bearing two fruits:

TABLE 23. RELATION BETWEEN WEIGHT OF THE SPUR AND NUMBER OF FRUITS BORNE BY IT

Variety	Branch	Spurs with one fruit		Spurs with two fruits	
		Number of spurs	Average weight (grams)	Number of spurs	Average weight (grams)
Baldwin	1	25	1.60	25	1.84
Baldwin	2	60	3.08	39	3.62

The relation between the vigor, or weight, of a spur and its tendency to produce more than one fruit is further emphasized by the data in table 24. The spurs included in the strong lot had much larger leaves, and more leaves to the spur, than those in the weak lot. All spurs were taken from the same branch. The table shows that the strong lot contained more spurs with two fruits than did the weak lot.

TABLE 24. SET OF FRUIT ON STRONG AND ON WEAK SPURS

Variety	Strong spurs		Weak spurs	
	Number of spurs	Percentage with two fruits	Number of spurs	Percentage with two fruits
Baldwin	94	34.0	33	15.2

The fact that fruit-setting spurs are heavier on the average than those that do not set fruit, suggests that the presence of the fruit on the spur may in itself be a stimulant to increase the weight of the spur. It is probable that the food which is translocated to the developing fruit accumulates just beneath the fruit stem, and in that way increases the weight of the fruit-bearing spur. Such an accumulation of food, however, is usually not apparent until after the fruits have attained considerable size. The presence of a fruit on a relatively weak spur does not materially increase its weight early in the season, nor does the absence of a fruit from a vigorous spur put it in the weak class. The weight of the spur is closely correlated with other conditions, as may be seen from the following paragraphs.

RELATION BETWEEN WEIGHT OF THE SPUR AND NUMBER OF FLOWERS TO THE SPUR

As previously shown, spurs with many flowers have a greater tendency to set fruit than those with a small number of flowers. The question whether there is a relation between the number of flowers on the spur and its weight, naturally suggests itself. Representative data regarding this question are contained in table 25. The figures are based on a consideration of spurs on a limb from a Maiden Blush tree. It is seen that spurs with many flowers are usually heavier than those with few flowers.

TABLE 25. RELATION BETWEEN WEIGHT OF THE SPUR AND NUMBER OF FLOWERS ON IT

Flowers to the spur	Number of spurs	Total weight (grams)	Average weight (grams)
4	6	10.58	1.76
5	19	51.77	2.72
6	18	60.41	3.36

RELATION BETWEEN WEIGHT OF THE SPUR AND LENGTH OF THE PREVIOUS SEASON'S GROWTH

Data are presented in tables 18 and 19 (pages 65 and 66) indicating that spurs making a relatively short growth during the season previous to the one in which they bear flowers are less likely to set fruit than spurs making a longer growth. Is there any relation between such length growth and the weight of the new spur growth arising from the terminal bud?

In a study of this question the flower-bearing spurs from several Baldwin limbs were divided into two lots. One lot consisted of spurs from buds terminating more than one centimeter of 1915 growth; in the other lot, the spurs were from buds terminating less than one centimeter of 1915 growth. The total weight of each lot and the average weight of the spurs are given in table 26:

TABLE 26. RELATION BETWEEN WEIGHT OF THE SPUR AND LENGTH OF THE PREVIOUS SEASON'S GROWTH

Variety	Branch	Spurs making more than 1 centimeter growth during previous season			Spurs making less than 1 centimeter growth during previous season		
		Number of spurs	Total weight (grams)	Average weight (grams)	Number of spurs	Total weight (grams)	Average weight (grams)
Baldwin	1	75	199.6	2.66	59	83.1	1.41
Baldwin	2	15	33.5	2.23	53	94.0	1.77
Baldwin	3	10	16.8	1.68	27	29.8	1.10
Baldwin	4	129	402.0	3.12	122	143.0	1.17
Total		229	651.9	2.85	261	349.9	1.34

The figures indicate that spurs making a relatively long growth during the preceding year will produce heavier and more vigorous buds in the following year than those making a short growth. That the spurs arising from buds terminating several centimeters of a given season's growth are more vigorous than spurs arising from buds on short spur-growth, may be observed even before the individual flower buds open (fig. 3).

It should not be assumed, however, that vigorous buds are produced only on relatively long growth and that spurs making a short growth are always weak. Cases in which the reverse conditions obtain are occasionally found. Nevertheless, the length of spur growth produced during the previous season forms a very convenient and satisfactory guide to the vigor of a spur, and the best criterion for a probable set is found in this character.

The advantages of having a basis for estimating the probable set are numerous. For example, plant breeders working on the apple might save considerable time and secure a higher percentage of set if they confined their work of cross-pollination to the vigorous, many-flowered spurs that have made several centimeters growth during the preceding season.

FIG. 3. LEAVES AND FLOWERS ON SPURS OF DIFFERENT VIGOR

Lower figure, a typical vigorous spur of the variety Tompkins King; upper figure, a spur below medium in vigor, of the same variety. The spurs were obtained just before the flower buds opened. The number of flowers (A, A'), the number and size of the leaves, and the length of the preceding year's spur growth (B, B'), may be compared. (½ natural size)

RELATION BETWEEN WEIGHT OF THE NEW SPUR GROWTH AND DIAMETER OF THE CONDUCTING TISSUE

In cutting off the spur growth just previous to weighing, it was observed that the diameter of the cylinder of conducting tissue varied between 1 and 2.5 millimeters (fig. 4). Closer inspection showed that the spurs with conducting tissue of large diameter had a greater leaf surface than spurs with conducting tissue of smaller diameter. The weights of new spur growth, together with the diameters of the conducting tissue of the spurs, are given in table 27. The material used was from a large limb on a Tompkins King tree. All flower-bearing spurs on the limb were considered.

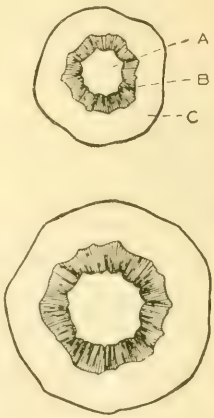

FIG. 4. CONDUCTING CYLINDERS IN SPURS OF DIFFERENT VIGOR

Cross section of a vigorous spur, below, and of a moderately vigorous spur above. A, pith; B, xylem (conducting tissue); C, cortex. The section was obtained just above the ring of scars. Outline from camera lucida drawing. × 6

The weights of the spurs show a relation to the diameters of the cylinders of conducting tissue. The smaller the conducting tissue is in diameter, the lighter is the new spur growth.

It should be noted that spurs with conducting tissue of large diameter are sometimes produced from buds that were terminal to less than one centimeter of spur growth. In all such cases, however, the spurs are large, in accordance with the preceding data. Likewise, when spurs show relatively small conducting-tissue cylinders, they are usually light in weight even tho they arise from buds terminal to several centimeters growth.

TABLE 27. RELATION BETWEEN DIAMETER OF CONDUCTING TISSUE AND WEIGHT OF SPUR

Relative diameter of conducting tissue	Number of spurs	Total weight (grams)	Average weight (grams)
Small (1–1.5 mm.)	74	110.7	1.50
Medium (1.6–2 mm.)	112	276.4	2.47
Large (2.1–2.5 mm.)	39	127.45	3.27

RELATION BETWEEN DIAMETER OF CONDUCTING TISSUE AND WEIGHT OF SPURS, FROM LIMBS HAVING A LIGHT BLOOM AND FROM THOSE HAVING A FULL BLOOM

As previously shown, the percentage of fruit set on limbs with relatively few flower-bearing spurs is greater than on limbs with an abundant bloom. It has been seen that heavy spurs have a greater tendency to set fruit than weak spurs, and that there is a relation between the weight of the spur and the diameter of the conducting cylinder in the spur. Are the spurs on limbs with a light bloom, heavier and more vigorous than the spurs on limbs with a full bloom? If so, is the conducting tissue of greater diameter in the former spurs than in the latter? These questions are answered by the data in table 28. Lot 1 consisted of all flower-bearing spurs from a limb on a Baldwin tree, and lot 2 of spurs from limbs on an Autumn Strawberry tree. Only twenty-five spurs from the limbs with a full bloom, and twenty-five from the ones with a light bloom, were considered in the latter case.

TABLE 28. RELATION BETWEEN DIAMETER OF CONDUCTING TISSUE AND WEIGHT OF SPURS, FROM LIMBS HAVING A LIGHT BLOOM AND FROM THOSE HAVING A HEAVY BLOOM

Lot	Relative diameter of conducting tissue	Spurs from limbs with a light bloom		Spurs from limbs with a heavy bloom	
		Number of spurs	Average weight (grams)	Number of spurs	Average weight (grams)
1	Small (1–1.5 mm.)	7	2.06	49	1.50
	Medium (1.6–2 mm.)	34	3.09	56	2.37
	Large (2.1–2.5 mm.)	14	4.01	20	3.10
	Total	55	3.20	125	2.16
2	Small	5	1.84	7	1.44
	Medium	16	2.53	11	2.39
	Large	4	3.38	7	2.63
	Total	25	2.53	25	2.19

The figures show that limbs with a light bloom have heavier spurs than limbs with a heavy bloom, and that spurs with conducting tissue of a given diameter taken from the former limbs weigh more than spurs with conducting tissue of the same diameter taken from the latter limbs. The leaves produced on spurs from limbs with a light bloom have a noticeably greater area than those produced on spurs which have conducting tissue of equal diameter but which were taken from limbs with a heavy bloom. The average leaf surface of several equally vigorous spurs obtained from these two sources was 125.34 and 86.51 square centimeters, respectively. The leaf area was measured by a planimeter.

RELATION BETWEEN WATER SUPPLY, LEAF AREA, AND PUSHING OF BUDS

It is generally understood that an abundant supply of water is a factor in producing large leaves. This was demonstrated by the following simple experiment. A number of dormant apple twigs were divided into two similar lots. The cut ends of the twigs were placed in beakers containing water. In one lot the cuts were renewed every few days and in the other lot they were renewed only seldom. The leaves of the former twigs were noticeably larger than those of the latter. This difference in size may be ascribed to the more abundant water supply obtained by the leaves on the twigs that had their cut ends frequently renewed.

A more elaborate experiment, which involved the forcing of water into the cut ends of the twigs, likewise indicated that there was a relation between the leaf surface and the water supply. The details of the apparatus used for this demonstration are shown in fig. 5. Tompkins King branches from three to four years old and approximately one meter long were used. The leaves on the twigs that had water forced into their bases were distinctly larger than those on untreated twigs.

This experiment, which was carried on in duplicate and which was repeated several times, yielded other results that may be of interest at this point. The buds on the check twigs, which were standing in a jar of water, opened about a week before the buds on the twigs that received their water supply under pressure. The first buds to open on the latter twigs were the small ones on relatively weak spurs. The first vigorous buds to push were those nearest the tops of the twigs. Droplets of sticky material oozed from all of the larger buds, which were found at the end of several centimeters of the previous season's growth. Similar exudations were observed on less vigorous buds produced on spurs arising near the bases of the twigs.

Apparently the delay in the pushing of buds was caused by excessive water pressure. The resistance encountered by the water passing thru

a meter of conducting tissue of the twig was apparently sufficient to reduce the pressure to a point at which bud-pushing could occur; hence, the first vigorous buds to open were those nearest the tops of the twigs. Weak spurs apparently offered greater resistance to the passage of water; hence, they pushed first because they were not oversupplied with water.

It has been shown previously that vigorous, heavy spurs are usually provided with conducting tissue of comparatively large diameter. This experiment shows that the large, plump buds which produce the heavy spurs are more abundantly supplied with water than the smaller buds.

The difference in leaf area between the vigorous and the weak spurs is probably due, in part at least, to the difference in water supply, or, more accurately, sap supply. The vigorous spurs have larger leaves than the weak spurs

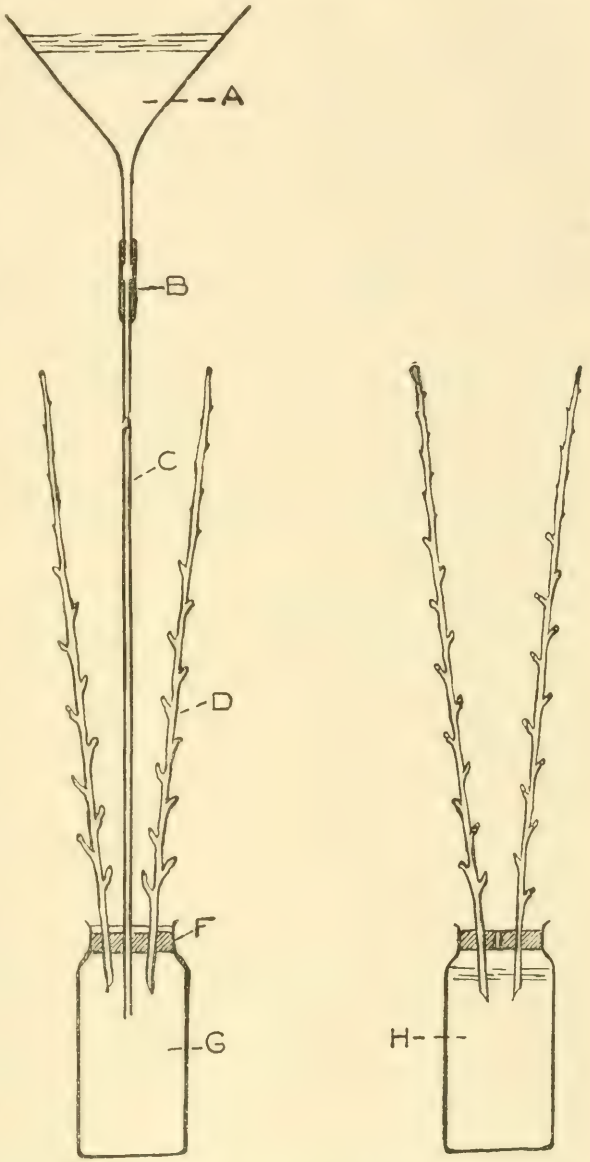

FIG. 5. APPARATUS FOR FORCING WATER INTO THE ENDS OF TWIGS

The pressure is supplied by a column of water three meters long. This column is maintained at approximately the same level by the water in the funnel, A, which is connected to the tube, C, by the union at B. The tube passes thru the cork, F. This cork is also provided with holes for the twigs, D. The twigs are from three to four years old and about one meter long. After these twigs and the tube have been inserted, the bottle, G, is filled with water. The cork is then flooded with warm paraffin. After this has become firm the pressure is applied. Check twigs are placed in the bottle H

because they have a greater diameter of conducting tissue and hence can obtain more sap.

It has been seen that the leaf area for spurs which have a conducting tissue of a given diameter and which were taken from limbs producing many flowers, is less than that for spurs with the same diameter of conducting tissue but taken from limbs producing few flowers. If the size of the leaves is an indication of the supply of sap that reaches the spur, it must be assumed that the former spurs are not so abundantly supplied as the latter even tho they have conducting tissue of the same diameter. It probably requires greater sap pressure to expand mixed buds, which contain both flowers and leaves, than is needed to push leaf buds. Moreover, the petals of the flowers will transpire considerable moisture. It seems reasonable, therefore, to assume that limbs producing a heavy bloom will supply less sap to the individual spur than similar limbs which produce a light bloom. The spurs from the former limbs are not so likely to set fruit as those from the latter limbs. Can this be due to an inadequate supply of sap?

RELATION BETWEEN AMOUNT OF LATERAL GROWTH FROM THE FLOWER-BEARING SPUR, AND FRUITFULNESS OF THE SPUR

The elongation of a spur that is producing flowers is dependent on the pushing of at least one lateral bud found on the current season's spur growth (fig. 1, page 51). In a few spurs the setting of a fruit inhibits the formation of a lateral bud. In some cases lateral buds are formed, but they do not push until the following year; in other cases, as much as twenty-five centimeters lateral growth is produced by the fruiting spur. All gradations between these extremes are found. The lateral growth may begin even before the flowers have opened, and by the time the fruit sets such growth may be several centimeters long. Observations here showed that fruit-setting on spurs that had made from five to ten centimeters of lateral growth was not uncommon. In fact it appeared that only a relatively small proportion of such spurs lost their fruit.

The amount of lateral growth produced by setting and by non-setting spurs derived from the same limb was recorded in several cases. Data for a Baldwin limb are given in table 29. It is seen that fruit is borne on spurs that produce much lateral growth as well as on those that produce little growth. The average weight of the lateral growth is greater in the spurs that bear fruit than in those that lose their fruit.

In other cases, the lateral growth produced by spurs taken from limbs that bore many fruits and from similar limbs that bore few fruits, was

TABLE 29. LATERAL SPUR GROWTH PRODUCED BY SETTING AND BY NON-SETTING SPURS FROM A BALDWIN LIMB

Amount of lateral growth	Produced by setting spurs	Produced by non-setting spurs
No growth	6	10
2 leaves	20	13
3 leaves	20	14
4 leaves	5	5
5 centimeters	1	0
Average weight of lateral growth	1.35 grams	0.79 gram
Average weight of spurs minus lateral growth	2.39 grams	1.31 grams

carefully examined. The results obtained with a pair of similar limbs from a Strawberry tree are recorded in table 30. One hundred of the largest spurs from each limb are considered.

TABLE 30. LATERAL GROWTH PRODUCED BY LARGE FLOWER-BEARING SPURS, FROM LIMBS SETTING FEW AND FROM THOSE SETTING MANY FRUITS

Amount of lateral growth	Produced by spurs from limbs setting few fruits	Produced by spurs from limbs setting many fruits
2 leaves	24	12
3 leaves	42	23
0.5–5 centimeters	29	34
5.1–10 centimeters	5	7
10.1–20 centimeters	0	10
Over 20 centimeters	0	14
Average weight of lateral growth	1.91 grams	3.70 grams

According to the table, the spurs from the fruitful branches have a tendency to produce more lateral growth than those from the less fruitful limbs. The average weight of the lateral growth produced by the former spurs is almost double that produced by the latter.

These figures indicate that fruit-setting is not opposed by vegetative activity as manifested by the amount of lateral spur growth. On the contrary, they suggest that the conditions which favor such growth are likewise favorable for the setting of fruit.

One of the essential conditions for the forcing of the lateral buds is an abundant supply of sap. It is well known that heavy pruning of an apple tree during the dormant season stimulates the production of vigorous shoots from the remaining growing points. Such pruning disturbs the equilibrium between the top and the root systems, and as a result there is an abundant supply of food and water for vigorous top growth.

It should also be pointed out that the lateral buds on many flower-bearing spurs can be forced into growth by severe pruning of the branch that produces the spurs. It seems reasonable, therefore, to assume that such lateral spur growth is an indication of an abundant supply of sap.

RELATION BETWEEN SAP SUPPLY AND FRUIT SETTING

Several of the observations previously recorded have suggested that an adequate supply of sap to the individual spur is an important factor in the setting of fruit. The object of the following experiments was to determine whether the percentage of spurs that set fruit could be increased by increasing the sap supply, or decreased by reducing the sap supply, to the individual spurs.

In the spring of 1916, large limbs, which were approximately five centimeters in diameter at their bases and which had a full bloom, were selected in pairs. The members of such pairs either formed the arms of a Y or arose within a foot of each other from the same parent branch. It was necessary to have the limbs of a given pair as nearly alike as possible in vigor, exposure, bloom, and size, and for this reason the selection of suitable pairs was no easy task.

In several cases one limb of a pair was sawed halfway thru near its base, and the second limb was left untreated or was pruned lightly by cutting out entire twigs containing both weak and vigorous buds. In other cases one limb was left unpruned and not sawed at its base, while the second limb had at least half the total number of branches removed. The object of sawing the branches at the base was to diminish the normal sap supply to the spurs on the limbs so treated. The aim of the severe pruning was to increase the flow of sap to the individual buds. The treatments were given just before the flowers opened. The results are recorded in table 31:

TABLE 31. PERCENTAGE OF FLOWER-BEARING SPURS SETTING FRUIT ON LIMBS WITH INCREASED AND ON THOSE WITH DIMINISHED SAP SUPPLY

Lot	Variety	Limbs with normal or increased sap supply				Limbs with normal or diminished sap supply			
		Treatment of limb*	Number of spurs	Number set	Percentage set	Treatment of limb*	Number of spurs	Number set	Percentage set
1	Tompkins King	2	71	14	19.7	4	166	15	9.0
2	Tompkins King	3	71	22	31.0	1	111	25	22.5
3	Strawberry	2	350	131	37.4	4	682	139	20.4
4	Strawberry	2	767	226	29.5	4	1,445	344	23.8
5	Baldwin	3	112	36	32.1	1	143	31	21.7
6	Baldwin	4	177	61	34.5	1	184	38	20.6
7	Baldwin	4	46	40	87.0	1	45	19	42.2
8	Baldwin	2	119	82	68.9	4	145	77	53.1

*Treatments: 1, treated limb sawed at base; 2, treated limb severely pruned; 3, treated limb slightly pruned; 4, limbs untreated.

In all cases the limbs that received relatively little sap had a smaller percentage of fruit-setting spurs than those receiving an abundant supply of sap. In a case not recorded in the table, members of a pair of branches on a Strawberry tree were left untreated. One arm had 1064 flower-bearing spurs, and the other arm had 1155. The percentage of spurs setting fruit was 22 for the former and 22.2 for the latter. The untreated limbs in lots 3 and 4, table 31, produced fruit on 20.4 and 23.8 per cent, respectively, of their spurs. These figures would seem to indicate that the range of variation in the percentage set is only slight when large numbers of spurs are involved.

As previously shown, the lateral growth produced by a flower-bearing spur may be taken as an index to the sap supply to that spur. In order to determine whether the treatments given had the desired effect of increasing or decreasing the sap supply, the lateral spur growth was carefully examined in each case. The analyses of the lateral growth produced by fifty of the largest flower-bearing spurs from a pruned branch and an equal number from an unpruned branch of a Strawberry tree are recorded in table 32:

TABLE 32. LATERAL GROWTH PRODUCED BY FLOWER-BEARING SPURS FROM A PRUNED BRANCH AND FROM AN UNPRUNED BRANCH

Amount of lateral growth	Produced by spurs from pruned branch*	Produced by spurs from unpruned branch†
2 leaves	5	17
3 leaves	6	19
0.5–5 centimeters	31	10
5.1–10 centimeters	4	3
Over 10 centimeters	4	1
Average weight of lateral growth	2.68 grams	1.90 grams

* 37.4 per cent of the flower-bearing spurs produced fruit.
† 20.4 per cent of the flower-bearing spurs produced fruit.

The spurs from the pruned branch made a more vigorous lateral growth than those from the unpruned branch. This indicates that the pruning actually increased the amount of sap available for each spur on the treated branch. The observations made in the remaining cases showed that the limbs which set most fruit to the hundred spurs also produced the most vigorous lateral spur growth.

The percentages of large and of small spurs setting fruit on the limbs that received relatively little sap to the spur, and on those that received relatively much sap to the spur, are recorded in table 33. The spurs were classed as large if they were produced from buds that were terminal

to one or more centimeters of the previous season's spur growth; if the spur growth was less than one centimeter, the spurs were classed as small.

TABLE 33. PERCENTAGE OF LARGE AND OF SMALL SPURS SETTING FRUIT ON LIMBS WITH DIMINISHED AND ON THOSE WITH INCREASED SAP SUPPLY

Lot	Variety	Large spurs			Small spurs		
		Diminished sap supply, percentage set	Increased sap supply, percentage set	Percentage gain	Diminished sap supply, percentage set	Increased sap supply, percentage set	Percentage gain
1	Tompkins King ..	25.0	26.1	1.1	6.8	16.6	9.8
2	Tompkins King ..	28.6	50.0	21.4	22.1	28.6	6.5
3	Strawberry.....	47.1	50.7	3.6	18.4	22.0	3.6
4	Strawberry.....	37.1	51.9	14.8	11.5	31.1	19.6
5	Baldwin.....	37.3	50.0	12.7	7.9	20.6	12.7
6	Baldwin.....	38.0	62.0	24.0	9.7	25.7	16.0
7	Baldwin.....	48.3	88.0	39.7	31.2	84.6	53.4
8	Baldwin.....	82.1	85.1	3.0	13.1	48.1	35.0

More fruit was produced on the large spurs than on the small spurs, as would be expected from previously recorded observations. The small spurs, as well as the large ones, are benefited by an increased supply of sap, as is indicated by the percentage gain.

The term *sap*, as used in the preceding paragraphs, has reference primarily to the watery solution taken up by the roots. No doubt some of the organic food stored in the roots, and in the trunk and the main limbs of the tree, would find its way into this solution before it reached the spur. It would be difficult to state definitely which was the more beneficial to the set of fruit — the water or the food material that it contained in solution. The fact that the vigorous spurs have a larger number of leaves and flowers than the weaker spurs, in itself suggests that the buds in which they were formed were well supplied with organic food. Müller-Thurgau (1898) has shown that many fruits are borne on limbs that have been girdled, while untreated limbs on the same tree with equally heavy blooms set relatively few fruits. Chandler (1913) has demonstrated that the sap derived from the cortex and the bark of girdled apple twigs is much denser than sap from similar limbs receiving no treatment. Gourley (1915) shows that more food is stored in fruiting than in non-fruiting spurs. There can be little doubt that an abundance of stored food is one of the factors favoring the setting of fruit. On the other hand, it must be borne in mind that heavy spurs usually have a large diameter of conducting tissue, which insures a good sap supply. Furthermore, the observations recorded above indicate that an abundant

supply of sap to spurs inadequately provided with storage tissue increases the ability of such spurs to set fruit.

FRUIT SETTING AS INFLUENCED BY VARYING AMOUNTS OF LEAF SURFACE ON THE FLOWER-BEARING SPUR

As previously shown, limbs with small leaves have a smaller proportion of fruitful spurs than similar limbs with large leaves. The area of the leaf surface seems to be closely correlated with the vigor, or weight, of the spur, which in turn shows a relation to the diameter of the cylinder of conducting tissue thru which the sap reaches the developing spur. The leaves might have several effects: they might assist in drawing water to the spur — the "pulling power of transpiration"; they might provide increased nourishment for the developing tissue; they might prove detrimental during conditions favoring incipient drying, by actually withdrawing moisture from the young flower or fruit. (Chandler, 1915). In order to gain some information regarding the influence of the bud leaves on the setting of fruit, the following experiments were carried out:

In the first experiment, a number of pairs of similarly located and equally vigorous spurs were selected. The vigor of the spurs was determined by the amount of leaf surface, and also by noting the length of the previous season's growth. The spurs of each pair were taken from the same parent branch and from points within a few inches of each other. Vigorous spurs only were selected because previous observations had shown that such spurs have the greatest tendency to set fruit. The importance of having spurs of similar location and vigor is obvious.

One spur of each pair was entirely defoliated, while the other served as a check, receiving no treatment. The leaves on the former were removed just before the blossoms opened in the spring of 1916. The set of fruit on the spurs was determined during the latter part of August. Unfortunately, many pairs had to be discarded because of aphid injury. Only healthy spurs were considered. The data are recorded in table 34.

The figures indicate that some of the defoliated spurs bear fruit, but the percentage of these is very much less than in the case of normal spurs. The high percentage of fruitful spurs recorded for the latter class reflects the influence of vigor.

The object of the next experiment was to determine the effect of partial and of complete defoliation of flower-bearing spurs on the setting of fruit. Several lots, each consisting of three similarly located and equally vigorous spurs, were selected. As a rule, vigorous spurs have from seven to ten first, or bud, leaves. One spur in each lot served as a check; the

TABLE 34. PERCENTAGE OF NORMAL AND OF DEFOLIATED SPURS BEARING FRUIT

Variety and tree	Normal spurs			Defoliated spurs		
	Total number	Number set	Percentage set	Total number	Number set	Percentage set
Baldwin, 1	16	14	87.5	16	6	37.5
Baldwin, 2	11	11	100.0	11	6	54.5
Baldwin, 3	32	23	71.9	32	12	37.5
Total	59	48	81.4	59	24	40.7
Tompkins King, 1	42	23	54.8	42	2	4.8
Tompkins King, 2	52	19	36.5	52	5	9.6
Tompkins King, 3	43	23	53.5	43	10	23.3
Total	137	65	47.4	137	17	12.4

second spur had all but two leaves removed; the third spur was entirely defoliated. The defoliation was done before the flowers opened in the spring of 1916. The set of fruit was determined during late August. Again many spurs were infested with aphids and had to be discarded. The data are recorded in table 35:

TABLE 35. PERCENTAGE OF NORMAL, OF PARTIALLY DEFOLIATED, AND OF COMPLETELY DEFOLIATED SPURS SETTING FRUIT

Variety	Normal spurs			Spurs with all but two leaves removed			Defoliated spurs		
	Total number	Number set	Percentage set	Total number	Number set	Percentage set	Total number	Number set	Percentage set
Baldwin	32	23	71.9	32	22	68.8	32	12	37.5
Tompkins King	51	19	37.3	52	18	34.6	52	5	9.6
Total	83	42	50.6	84	40	47.6	84	17	20.2

The figures show that spurs with two leaves set approximately as well as spurs with all leaves. The presence of a small amount of leaf surface apparently offsets the harmful effects of entire defoliation.

Many spurs set more than one fruit. The percentage of such spurs in defoliated and in check lots is given in table 36. The normal spurs, as might be expected, are more likely to produce two fruits than are defoliated spurs. The percentage of spurs setting more than one fruit is three times as great in the case of the untreated spurs as in the defoliated lot.

TABLE 36. NUMBER OF FRUITS TO THE SPUR ON NORMAL AND ON DEFOLIATED SPURS

Number of fruits to the spur	Number of spurs with respective number of fruits	
	Normal spurs	Defoliated spurs
1	35	21
2	19	3
3	4	0
Percentage of spurs setting more than one fruit	39.7	12.5

These results are interesting because they show that a small leaf surface in itself, such as is found on spurs on weak limbs or on those with a heavy bloom, is not accountable for a poor set of fruit. The data at hand do not afford an adequate explanation for the results obtained. On the basis of observations and experiments presented later, however, it seems reasonable to assume that the leaves favor fruit-setting on vigorous spurs because they assist in drawing sap to the fruit.

INFLUENCE OF SUNLIGHT ON THE SETTING OF FRUIT

In order to learn whether or not a variety is self-sterile, cross-pollination is prevented by inclosing the flower spurs in sacks. According to Ewert (1907), such treatment subjects the inclosed spurs to unnatural conditions which may be unfavorable for the setting of fruit. The object of the following experiments was to determine the effect of excluding sunlight on the setting of fruit.

Some vigorous spurs were inclosed in brown opaque paper bags, and some in white translucent paper bags. Only the most vigorous spurs were inclosed, and for each spur inclosed in a translucent sack a similar spur arising from the same parent branch was inclosed in an opaque sack. The spurs were sacked in the spring of 1916, before the clusters of flowers had separated. The set of fruit was determined in late summer. Unfortunately a large number of the sacked spurs had to be discarded because of aphid work. The data obtained, however, are very suggestive. They are recorded in table 37, in which it is seen that over twice as many spurs set fruit in the translucent sacks as in the opaque sacks.

The following notes may be of interest: On May 17, 1916, the flowers in the opaque bags had white petals, and all flowers in the cluster were open; the flowers in the translucent bags had pink petals, and were somewhat further advanced than the flowers in exposed clusters. The stigmas

TABLE 37. SET OF FRUIT ON SPURS INCLOSED IN OPAQUE BAGS AND ON SPURS INCLOSED IN TRANSLUCENT BAGS

Variety	Branch	Spurs inclosed in opaque bags			Spurs inclosed in translucent bags		
		Total number	Number set	Percentage set	Total number	Number set	Percentage set
Baldwin	1	25	7	28.0	25	11	44.0
Baldwin	2	19	3	15.8	19	14	73.7
Total	.....	44	10	22.7	44	25	56.8

on all inclosed flowers were green; those on exposed flowers had a reddish tinge, even before the petals unfolded. The leaves on all the inclosed spurs were smaller than those on the exposed spurs. At the time when the fruit-setting spurs were counted, it was observed that there was a tendency for fruit in the translucent sacks to attain the June-drop size before it fell, whereas in the opaque sacks the fruit fell when very small. All the flowers in the experiment were self-pollinated if pollinated at all.

The figures indicate that exposure to sunlight is an added advantage in fruit setting. The results agree with those of Lubimenko (1908), who finds that illumination is essential during the early stages of development of young fruit.

Inclosing the spurs in bags inhibits the free circulation of air, and transpiration is probably reduced as a result. The air temperature in the brown bags would be higher than that in the white bags on sunny days. The diffused light in the translucent sacks would be sufficient for some photosynthetic activity, while practically all light is excluded from the opaque sacks. The leaves in the former, being exposed to light, would probably have greater osmotic properties than those in the dark (Chandler, 1913). The advantage of having leaves with the greater osmotic properties would be that more sap would tend to flow in the direction of the spurs which produce such leaves. This sap would be available for the setting of fruit.

RELATION BETWEEN SEED FORMATION AND FRUIT DEVELOPMENT

It is commonly supposed that the apples which are poorly fertilized and which consequently develop few seeds, tend to fall off during the June drop. That there is a close relation between seed formation and fruit development is shown in the following paragraphs.

Number of seeds in fruit that sets and in fruit that drops

The drop apples have fewer seeds on the average than are found in the average fruit that remains on the tree, as shown by the representative data in table 38:

TABLE 38. AVERAGE NUMBER OF SEEDS IN FRUIT THAT DROPS AND IN FRUIT THAT REMAINS ON THE TREE

Variety	Drop fruit		Attached fruit	
	Number of fruits	Average number of seeds to the fruit	Number of fruits	Average number of seeds to the fruit
Baldwin	48	3.38	47	4.47
Rhode Island	66	3.51	29	6.43
Maiden Blush	65	3.94	66	6.28

The number of seeds found in individual fruits that have fallen and in individual fruits taken from the tree are given in table 39. The column on the left contains the number of seeds to the fruit. The figures in the other columns give the number of fruits showing the respective number of seeds. It is seen that many attached fruits have relatively few seeds and some drops have a high seed content. This suggests that other factors, in addition to fertilization or pollination, are responsible for the set of fruit.

TABLE 39. NUMBER OF SEEDS IN FRUIT THAT DROPS AND IN FRUIT THAT REMAINS ON THE TREE

Number of seeds to the fruit	Baldwin		Rhode Island		Maiden Blush	
	Attached fruit	Drop fruit	Attached fruit	Drop fruit	Attached fruit	Drop fruit
1	.....	2	.....	6	1	3
2	5	16	.....	13	4	17
3	9	12	4	18	9	17
4	9	7	1	9	7	8
5	14	4	5	15	4	6
6	6	6	5	2	10	7
7	3	0	5	1	10	3
8	1	1	6	2	11	4
9	.....	.....	1	.....	6	.....
10	.....	.....	1	.....	2	.....
11	.....	.....	1	.....	0	.....
12	.....	.....	.....	.....	1	.....
13	.....	.....	.....	.....	1	.....

Osterwalder (1907 a) examined the seeds in fruit that had fallen from the tree. He found that sixty-five per cent of these contained embryos, while about seventy-five per cent of the seeds in the fruit that remained on the tree contained embryos.

Relation between number of seeds and size of fruits

Müller-Thurgau (1898) has studied the relation between the number of seeds and the size of berry in the grape. For eighteen varieties of grapes he finds the following averages:

Weight of flesh of 100 seedless grapes, 42.8 grams
Weight of flesh of 100 1-seeded grapes, 144.0 grams
Weight of flesh of 100 2-seeded grapes, 209.3 grams
Weight of flesh of 100 3-seeded grapes, 253.9 grams

He also presents data indicating that a similar relation exists in the case of apples and pears, and his results are substantiated by Ewert. The general law, that the more are the seeds the larger is the apple, is illustrated by the figures in table 40. These data were obtained in 1915 from trees in the experiment station orchard at Cornell.

TABLE 40. NUMBER OF SEEDS AND SIZE OF FRUITS

Number of seeds to the fruit	Maiden Blush		Baldwin	
	Number of fruits	Average diameter (millimeters)	Number of fruits	Average weight (grams)
1	2	8.0	2	2.98
2	16	10.5	4	3.27
3	27	11.9	5	3.60
4	10	13.2	11	4.84
5	5	14.6	5	5.47
6	6	16.8	9	6.53
7	3	17.7	.....	.....
8	2	19.8	.....	.....
9	2	19.0	.....	.....

This relation, being based on averages, will naturally not cover all cases. During preliminary observations, few-seeded apples were found which were as large as many-seeded fruits, and not infrequently even larger. Further study showed that in a number of cases the relatively small fruit with many seeds was associated with a small spur. This suggested that the vigor of the spur, as determined by its weight, might be

a factor, together with the number of seeds, in determining the size of the fruit. Accordingly, accurate weights of several hundred spurs, together with the weight of the fruit borne on these spurs and the number of seeds contained in each fruit, were recorded. The weighings were made during July of 1915 and July of 1916. The data obtained in this way are analyzed from several points of view in the following paragraphs.

Size of fruit constant, number of seeds varying.— In the cases recorded in table 41, the fruits in each lot are approximately constant in weight but the number of seeds varies. It should be mentioned that the fruits in each lot were produced on the same branch. The branches were approximately ten years old and measured about one and one-half centimeters in diameter at their bases.

TABLE 41. WEIGHT OF FRUIT CONSTANT, NUMBER OF SEEDS AND WEIGHT OF SPURS VARYING

Lot	Variety	Weight of fruit (grams)	Number of seeds to the fruit	Weight of spurs (grams)
1	Tompkins King	14.95	2	5.54
		14.72	4	5.05
		14.86	6	2.31
		13.30	7	1.98
2	Tompkins King	16.05	2	3.97
		16.96	6	1.45
3	Tompkins King	30.96	3	6.09
		31.68	6	3.75
4	Tompkins King	95.90	2	5.05
		97.10	4	2.40
5	Rhode Island	25.58	3	4.86
		25.31	8	2.28
6	Westfield	21.64	5	2.33
		21.87	8	1.31

If the weights of the spurs that bore the few-seeded fruits are compared with the weights of those that bore the many-seeded fruits, it is seen that in all cases the vigor was greater in the spurs bearing the few-seeded fruits. In other words, the smaller the spur, the greater is the number of seeds required to produce a fruit of a given size.

Weight of spur constant, number of seeds varying.— The weight of spurs in each group is approximately constant in the cases recorded in table 42. The number of seeds in the fruits borne by these spurs varies. In each lot, as before, the spurs were produced on the same parent branch.

TABLE 42. WEIGHT OF SPUR CONSTANT, NUMBER OF SEEDS AND WEIGHT OF FRUIT VARYING

Lot	Variety	Weight of spur (grams)	Number of seeds	Weight of fruit (grams)
1	Tompkins King	4.76	1	12.87
		4.65	5	26.80
2	Tompkins King	3.38	1	8.53
		3.40	5	20.78
3	Tompkins King	3.51	2	12.77
		3.53	9	20.08
4	Tompkins King	1.54	2	6.37
		1.60	6	13.76
5	Tompkins King	4.31	2	86.10
		4.34	4	103.00
6	Tompkins King	4.87	2	84.20
		4.90	5	112.70
7	Tompkins King	3.41	4	38.31
		3.40	7	50.88
8	Tompkins King	4.60	2	23.55
		4.90	5	43.87
9	Baldwin	2.47	3	16.28
		2.47	6	23.73
10	Baldwin	3.47	2	45.80
		3.55	5	58.60
11	Baldwin	2.48	3	47.60
		2.47	5	60.40
12	Baldwin	4.51	3	39.40
		4.56	6	60.00
13	Baldwin	3.75	3	31.97
		3.74	7	42.84
14	Baldwin	3.63	3	35.25
		3.61	5	40.12
15	Baldwin	2.34	3	15.72
		2.43	7	21.01
16	Westfield	2.28	3	16.84
		2.24	5	18.72
		2.21	8	23.15
		2.26	9	24.02
		2.22	11	29.40
17	Fallawater	1.64	2	26.13
		1.65	5	35.97

The data show that when the weight of the spur is constant, the size of the fruit varies with the number of seeds. In other words, the size of the fruit is determined chiefly by the vigor of the spur and the seed content of the fruit.

Weight of spur constant, number of seeds constant, size of embryo varying.— Theoretically, according to one interpretation of the above hypothesis, if spurs of approximately equal vigor are chosen which bear fruits containing the same number of seeds, the fruits borne on these spurs should be approximately equal in weight. Or, stated in a different way, if the fruits vary in size while the seed number remains the same in each, a difference would be found in the vigor of the spurs producing these fruits, and furthermore one would expect to find the largest apple on the most vigorous spur. That these theoretical results are not always obtained may be seen from the examples in table 43:

TABLE 43. WEIGHTS OF FRUITS HAVING THE SAME NUMBER OF SEEDS, AND WEIGHTS OF THE SPURS THAT BEAR THE FRUITS

Lot	Variety	Number of seeds	Weight of fruit (grams)	Weight of spur (grams)
1	Baldwin	4	6.37	4.28
		4	6.24	3.20
2	Baldwin	4	5.12	3.55
		4	5.07	1.90
3	Tompkins King	6	41.90	2.54
		6	29.86	2.59

These data seem to disprove the existence of a direct relation between size of fruit, vigor of spur, and number of seeds. The emphasis, however, is to be placed on seed content rather than mere number of seeds.

In studying the seeds, one cannot help noticing marked differences in the size of the seeds in given fruits. The embryos in the seeds likewise show considerable variation. The embryo is readily dissected from the seed by placing the seed flatwise between the thumb and the forefinger, with the lateral edge upward, cutting the edge with a sharp scalpel, and pressing the embryo out of the seed coat.

In several cases the number of embryos found in the seeds of a given fruit and the length of the individual embryo were recorded, along with the weight of the fruit and the weight of the spur on which the fruit was borne. These data are given in table 44. The figures under the column headed *Length of embryo* show the number of seeds in each fruit and the length in millimeters of the embryo in each seed; for example,

6–5–5 indicates that the fruit contained three seeds, which in turn contained embryos measuring six, five, and five millimeters, respectively. The fruits in the different lots are arranged in order of their weight. The weights of the spurs bearing the fruit are also given. The fruits in each lot were produced on the same branch.

TABLE 44. WEIGHT OF FRUIT, WEIGHT OF SPUR, AND LENGTH OF EMBRYO

Lot	Variety	Weight of fruit (grams)	Weight of spur (grams)	Length of embryo (millimeters)
1	Tompkins King	77.00	3.60	6–5–5
		69.00	5.68	7–7–5
		68.25	6.12	7–5–3
		65.31	6.71	5–5–5
		52.20	2.45	7–7–6
2	Baldwin	37.58	4.55	7–7–7
		35.25	3.63	7–4–2
		33.95	3.53	7–5–2
		33.72	3.16	7–6–6
		31.97	3.75	7–3–3
		30.86	2.93	7–7–3
		30.11	3.85	6–5–3
		26.42	2.62	7–6–3
3	Baldwin	42.84	3.76	8–7–7–7–6–4–1
		41.84	6.06	8–7–6–5–3–1–0
		41.71	3.14	8–7–6–6–6–4–2
		40.28	3.43	7–7–7–5–4–4–1
		38.13	1.97	9–8–7–7–6–3–3
		35.63	3.48	7–7–7–5–5–1–1

The data show that in most cases the size of the fruit can be accounted for by taking into consideration the weight of the spur and the length of the embryos in the seeds. The fruit with the longest embryos will usually be the heaviest if it is borne on the most vigorous spur. A fruit may attain a good size on a relatively small spur if its seeds contain large embryos. Conversely, a small fruit borne on a large spur is the result of a small embryo.

In this connection it should be noticed that a small spur may produce a large fruit, and a large spur a relatively small fruit. These facts afford additional evidence to show that the weight of the spur is not markedly influenced early in the season by the fruit borne on it.

That exceptions are found to the general rule is not surprising. One could hardly expect that a single measurement would tell all about the possibilities of the embryos for fruit formation. Some embryos are plumper than others even tho they are of the same length. Some have

different shapes. Furthermore, they vary in color, some being ivory white, others yellowish, others hyaline in appearance. All this suggests a difference in quality, such as might result from cross-pollination, for example.

Number of seeds and seed value.— As shown above, the seed value as expressed by the length of the embryo may vary in the different fruits even tho the number of seeds is the same. It is entirely possible that a many-seeded fruit may have a seed value which is below the normal for that number. It may be equal to, and in some cases even less than, the seed value of a fruit with few seeds. Such an assumption is borne out by the fact that in a large number of three-seeded Baldwin fruits, seventy per cent of the embryos were above medium length — five millimeters — while in many-seeded fruits of the same variety only about fifty per cent of the embryos were large. If the ratio of the weight of the spur to the weight of the fruit is greater in a few-seeded fruit than in a many-seeded fruit borne on a similarly located spur of equal weight, one would be justified in assuming that the seed value of the latter fruit was below normal. A specific case may be taken for example as follows:

Number of seeds	Weight of spurs (grams)	Weight of fruit (grams)
2	2.05	49.1
5	2.00	44.3
5	2.00	62.7

These spurs were borne on the same twig and they produced their fruits under similar external conditions so far as could be seen. Obviously, the five-seeded fruit that weighs only 44.3 grams has a seed value below normal. This seed value is equivalent to that of a few-seeded fruit. There may be found a fruit weighing less than 49 grams which nevertheless has a high seed value. Such a fruit, however, would be on a spur weighing less than two grams; thus, a fruit with four seeds, weighing 35.5 grams, was produced on a spur that weighed one gram.

It therefore becomes necessary to modify the general statement that the size of fruit is proportional to the number of seeds. It would be more nearly accurate to say that the vigor of the individual spur and the seed value of the individual fruit determine the size of the fruits derived from the same limb and borne under otherwise similar conditions. This statement includes the prominent part played by the spur, and it also emphasizes seed value rather than number of seeds. It is, of course, very necessary to choose spurs borne under otherwise similar conditions, as is shown later.

Relation between seed value, weight of spur, and set of fruit

That the vigor, or weight, of the flower-bearing spur is an important factor in determining whether the flowers will set fruit, has been suggested by data previously recorded. Figures have likewise been presented which show that the drop apples contain fewer seeds than the fruit that remains on the tree. This indicates that the number of seeds, which presupposes effective pollination, likewise plays a part in determining the set of fruit.

Since, then, the smaller spurs are more likely to lose their fruit than the larger, and since the average number of seeds is less in the drops than in the setting fruit, it is apparent that most of the few-seeded drops were borne on small spurs.

But, as has been shown, there are many fruits that remain on the tree even tho they have few seeds — less in some cases than are found in the average fruit that has dropped. According to the statements in the preceding paragraph, these few-seeded fruits would have fallen if they had been borne on relatively light spurs. Therefore it must be assumed that they were produced on vigorous spurs. Since relatively few fruits with many seeds are found among the drops, and since there is no basis for assuming that the flowers on less vigorous spurs will necessarily be poorly pollinated and hence develop few seeds, one might expect to find fruit with many seeds on relatively weak as well as on vigorous spurs. To account for the drops with many seeds it must be assumed, in order to be consistent, that these came from very weak spurs. Then, too, they might have a low seed value even tho their seed number is high.

Stating this hypothesis in other words, few-seeded fruits, or, more accurately, fruits with a low seed value, are borne only on the heavier spurs, while many-seeded fruits, or those with a high seed value, may be borne on relatively light as well as on vigorous spurs.

In order to test this hypothesis, the weights of several hundred spurs, together with the weights of the fruits borne on them and the number of seeds in each fruit, were obtained during late July and early August. The weight of spur includes all of the present season's growth minus the lateral growth. The spurs were cut from the twig in the manner previously described (page 67). The spurs obtained from each twig or branch were divided into two lots, one containing the fruits with a high seed value and the other including the fruits with a low seed value. The determination of the seed value of a fruit was based on the observations regarding the relation between number of seeds, vigor of spur, and size of fruit. These observations also afforded the suggestions for the study of the relation between number of seeds, size of spur, and set of fruit. The results are recorded in table 45:

TABLE 45. WEIGHTS OF SPURS BEARING FRUIT WITH A LOW SEED VALUE AND OF THOSE BEARING FRUIT WITH A HIGH SEED VALUE

Lot	Variety	Fruits with a low seed value			Fruits with a high seed value		
		Number of spurs	Average weight of spurs (grams)	Average weight of fruit (grams)	Number of spurs	Average weight of spurs (grams)	Average weight of fruit (grams)
1	Baldwin	24	3.46	20.33	17	2.73	46.39
2	Baldwin	14	3.56	30.94	8	2.73	39.08
3	Baldwin	16	3.91	33.28	27	2.64	34.25
4	Baldwin	25	3.12	48.29	19	3.00	56.52
5	Baldwin	12	3.56	20.11	8	2.60	23.81
6	Fallawater	33	2.58	26.19	16	2.46	35.79
7	Rhode Island	15	4.33	23.89	13	4.39	31.16
8	Tompkins King	7	3.95	26.62	3	2.36	31.30
9	Tompkins King	6	4.49	28.72	7	5.02	42.93
10	Tompkins King	10	4.44	49.29	5	2.61	51.41
11	Tompkins King	10	4.78	65.06	5	2.61	67.30
12	Tompkins King	18	4.25	55.92	10	4.10	122.50
13	Tompkins King	32	2.92	13.80	19	2.05	16.78
14	Tompkins King	32	3.33	15.15	20	3.27	19.58
15	Westfield	24	2.43	19.19	20	2.25	25.15
	All varieties	278	3.41	.....	197	2.90	.....

It is seen that in practically all cases the spurs bearing fruits with a low seed value are heavier than those bearing fruits with a high seed value. In the average of all varieties, the spurs bearing fruits with a low seed value are 17.6 per cent heavier than those bearing fruits with a high seed value. There is no apparent reason why a vigorous spur should not bear fruit with a high seed value, hence it is not surprising that individual lots, such as numbers 7 and 9, should show heavier spurs for many-seeded than for few-seeded fruits. When the average weight of spurs for a lot in which the fruit has a low seed value is approximately the same as for the fruit from the same branch with a high seed value, the weight of the fruit in the latter case is considerably greater than in the former; this is shown by lots 4, 6, 7, 12, and 14. In those cases in which the fruits are almost of the same weight for many-seeded and for few-seeded lots, such as lots 3, 10, and 11, the spurs in the latter are the heavier.

In table 46 only half of the total number of spurs are considered — that half containing the smaller spurs. In this table the differences before noted are more marked because of the elimination in each class of the half containing the heavy spurs. The smaller spurs bearing fruit with a low seed value are 28 per cent heavier than the smaller spurs bearing fruit with a high seed value.

TABLE 46. WEIGHTS OF SMALLER SPURS BEARING FRUIT WITH A LOW SEED VALUE AND OF THOSE BEARING FRUIT WITH A HIGH SEED VALUE

Variety	Fruits with a low seed value		Fruits with a high seed value	
	Number of spurs	Average weight of spurs (grams)	Number of spurs	Average weight of spurs (grams)
Baldwin	12	2.45	9	1.80
	7	2.44	4	2.30
	8	3.28	14	2.03
	12	2.48	9	2.10
	6	3.00	4	2.18
Fallawater	17	1.89	8	1.24
Rhode Island	7	3.63	6	3.24
Tompkins King	3	3.17	2	2.24
	3	4.18	3	3.29
	5	3.49	3	2.00
	5	4.26	3	2.08
	9	3.29	5	3.01
	16	2.02	10	1.44
	16	2.58	10	2.25
Westfield	12	2.18	10	1.64
All varieties	138	2.65	100	2.07

A poorly fertilized flower can develop into a fruit, provided it is borne on a vigorous spur; a weak spur, on the other hand, will mature only a fruit that is developing many good seeds.

These data suggest that there is greater need for cross-pollination when the flowers are produced on trees growing under conditions that are unfavorable for the production of strong spurs, than for trees under favorable conditions. It is well known that apple trees growing in sod will usually produce less fruit than similar trees growing under cultivation. Do sod trees produce less vigorous spurs than cultivated trees, and consequently demand better fertilization of the flowers to insure a set of fruit?

The following observations may throw some light on this question. A large number of apples from a mature Tompkins King tree growing in sod contained an average of 6.1 seeds. Fruits from a tree of the same age and variety growing in a cultivated orchard had an average of 3.8 seeds. The orchards in question were about half a mile apart. In both, the opportunities for cross-pollination were good. It seems reasonable to suppose

that the apples which dropped from the trees in the sod orchard contained more seeds to the fruit than the drops from the well-cared-for trees. In other words, the former trees required the stimulus of many seeds to set fruit, while the latter set fruit even tho few seeds were developed.

OBSERVATIONS CONCERNING SOME OF THE PHYSIOLOGICAL EFFECTS OF SEEDS

It has been shown that the size of the fruits borne on a given branch under certain external conditions is dependent on the vigor of the spur and the seed value. The higher the seed value, the larger is the apple under conditions otherwise similar. This suggests that the seeds exert some influence which increases the supply of sap to the fruit in which they are borne.

The heavier and more vigorous spurs, as previously shown, are provided with a large diameter of conducting tissue, which permits of more abundant sap flow. Large spurs that have good conducting tissue are able to set fruit with a low seed value, whereas the fruits on the smaller spurs must have a high seed value if they are to continue development. One might assume that the handicap of poor conducting tissue in the small spur is overcome by the pull on the sap flow exerted by the seeds. Small spurs require considerable help in order to provide an adequate supply of sap for a developing fruit, while large spurs need relatively little help. The following direct evidence is presented to show that many-seeded fruits actually do exert a greater pull on the sap flow than do few-seeded fruits.

Withdrawal of water by leaves from fruits with varying numbers of seeds

A number of spurs, each bearing one fruit, were taken from a branch of a Tompkins King tree in July, 1915. All but three of the leaves were removed from each spur, the leaves remaining being approximately of the same size and therefore the leaf surface on one spur being equal to that on any other. The fruits were coated with melted paraffin to prevent transpiration, and the spurs were then exposed in the laboratory. Some spurs without fruit and some detached fruits were exposed at the same time.

In conformity with the observations of Chandler (1914), the leaves on spurs that bore fruit remained turgid for several days, while the fruits on such spurs wilted and became shriveled. The leaves on spurs without fruit soon became dry and crisp. The detached fruits remained firm. That the leaves on the spurs bearing apples obtained their moisture from the fruit, is obvious. The point which is of special interest in this connection

is that even tho the fruits were equally large in all cases, and even tho the leaf area was approximately the same on all spurs, some fruits remained firmer than others. The leaves on the spurs having the firm fruits dried before those on the spurs bearing the shriveled fruits. Examination showed that the badly shriveled fruits had fewer seeds than those which were comparatively firm. The greater the number of seeds, the less water was withdrawn from the fruit by the leaves.

In several cases the fruit had not shriveled uniformly, but one side remained firm while the other was decidedly wrinkled. In most cases of this nature, the shriveled side corresponded to a seedless cavity while the firm side usually contained two seeds in the corresponding cavity (fig. 6). Similar results were obtained in repeated experiments, altho exceptions to the general rule were occasionally found. Such exceptions

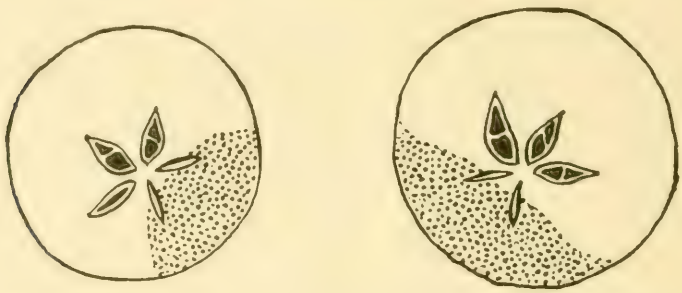

FIG. 6. CROSS SECTIONS OF APPLES, SHOWING THE RELATION BETWEEN SEEDS AND THE ABILITY TO WITHHOLD WATER

The dotted area indicates the wilted part. It is associated with the seedless cavities

might be explained on the basis of seed value. In these experiments it is essential to choose spurs that bear fruit under exactly similar conditions, as is emphasized later.

Depression of freezing point by sap from fruits with varying numbers of seeds

As Chandler (1913) has shown, sap obtained from leaves freezes at a lower temperature than sap obtained from green fruit. The movement of sap from fruit to leaves is accounted for by osmosis. Since leaves withdraw water from many-seeded fruits less rapidly than from few-seeded fruits, one might expect that the sap from fruits with many good seeds would depress the freezing point more than sap from few-seeded fruits.

A few preliminary determinations regarding this point were made in August, 1915. The results obtained are very suggestive. The sap was

expressed from apples whose seed content was known. A single apple did not yield sufficient sap, hence three or four fruits with the same number of seeds were used in each case. The apples were first ground up in a food chopper, and the sap was then expressed from the pomace. The freezing points of this sap were obtained by means of a Beckman apparatus. The results are given in table 47, which shows that the sap from fruits with few seeds depresses the freezing point less than does the sap from many-seeded fruits. It should be pointed out, in this connection, that these freezing points are for sap expressed from the live tissue of the fruits. If the tissue had been frozen before the sap was expressed the depression of the freezing point would no doubt have been greater in each case.

TABLE 47. DEPRESSION OF FREEZING POINT BY SAP FROM FRUITS WITH VARYING NUMBERS OF SEEDS

Variety	Sap from fruits with few seeds		Sap from fruits with many seeds	
	Number of seeds in fruit	Depression of freezing point (degrees centigrade)	Number of seeds in fruit	Depression of freezing point (degrees centigrade)
Tompkins King	2	1.081	6	1.119
Baldwin	2	1.123	6	1.153
Westfield	5	0.972	9	1.024
Fallawater	3	1.009	5	1.027
Baldwin	3	0.809	6	0.909
Rhode Island	3	0.900	5	0.967
Average	3	0.982	6.2	1.033

The average weight of the spurs and of the fruits is given, in connection with the number of seeds and the depression of the freezing point, in table 48. These data likewise indicate that the sap of many-seeded fruits is capable of developing a greater osmotic pressure than the sap from few-seeded fruits. This fact suggests why the many-seeded fruits do not lose water as readily as do the few-seeded fruits.

That the term *greater seed value* is more nearly accurate than *many seeds* is indicated by the last experiment in table 48. The eight-seeded fruits in this case have a lower seed value than the three-seeded fruits. As would be expected under such conditions, the three-seeded fruits show the greater sap density.

TABLE 48. DEPRESSION OF FREEZING POINT BY SAP FROM FRUITS WITH VARYING NUMBERS OF SEEDS, WEIGHTS OF SPURS, AND WEIGHTS OF FRUITS

Lot	Average weight of spurs (grams)	Average weight of fruit (grams)	Number of seeds	Depression of freezing point (degrees centigrade)
1	5.47	68.35	3	1.112
	2.11	68.53	5	1.152
2	5.12	86.40	4	1.112
	2.31	51.24	5	1.182
3	4.21	26.29	3	0.900
	4.32	25.62	8	0.867

Relation between formation of seeds and symmetrical development of fruit

It may be of interest in this connection to record observations regarding the symmetry of fruits. Müller-Thurgau and Ewert give figures in which the amount of flesh of the fruit is more or less proportional to its seed content. If the seeds are confined to one side of an apple, only that side will be fully developed while the other side will be much smaller. Such unsymmetrical development is found in a high proportion of the fruits that are lost during the June drop. Comparatively few of the normal apples — those free from insect, disease, and other blemishes — which remain on the tree are one-sided, altho mature fruits with one or more of their cavities seedless are frequently found. These observations can be explained in the following manner:

As has just been shown, fruits with many seeds, or with a high seed value, apparently have denser sap than few-seeded fruits. Such many-seeded fruits can therefore exert a greater pull on the sap flow. If the fruit is borne on a weak spur, the seeds play a very important part in obtaining sufficient food and water because the sap must pass thru a poorly developed conducting tissue. If a fruit with a seedless cavity happens to develop on a weak spur, the side without seeds suffers first and falls behind in growth. Sooner or later the poorly pollinated fruit on the weak spur drops, and hence many of the drops are one-sided.

Poorly pollinated fruit that remains on the tree is usually borne on vigorous spurs. Such spurs are generally provided with good conducting tissue which can supply abundant sap with comparatively little stimulation such as is afforded by seeds. The influence of the seeds in fruits developed on strong spurs is therefore only a secondary influence, and

the presence or absence of seeds in one cavity of the fruit makes relatively little difference in the growth of the corresponding side of the apple

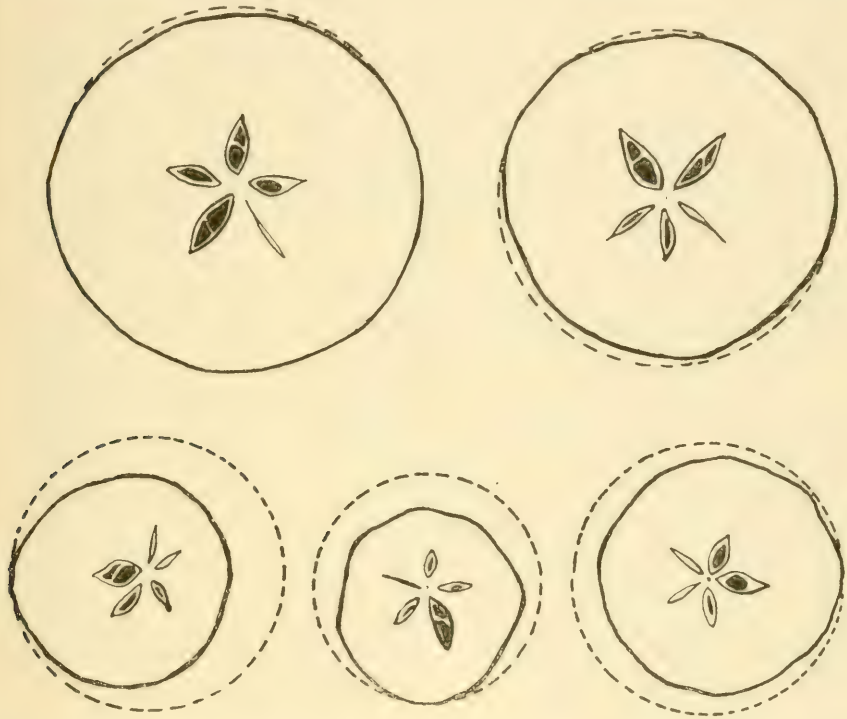

FIG. 7. CROSS SECTIONS OF APPLES THAT DROPPED AND OF THOSE THAT REMAINED ON THE TREE

The circles surrounding each section are drawn with the longest possible radius extending from the center of the core to the surface. The smaller apples are the June drops. In these the fruits fall behind in their development on the seedless side. In the apples remaining on the tree (the larger sections) asymmetry is not so closely correlated with the seedless cavity

(fig. 7). Fruits remaining on weak spurs after the June drop are normally well pollinated and generally develop seeds in all cavities; hence they too will be symmetrical.

RELATIONS TO BE CONSIDERED IN CHOOSING FRUITS BORNE UNDER SIMILAR CONDITIONS

As pointed out previously, it is very essential that fruits intended for study of the relations between size of fruit, number of seeds, and vigor of spur should be produced under exactly similar conditions. The following paragraphs suggest some of the things which must be kept in mind in choosing fruits suitable for this purpose.

Position of the fruit on the spur, and number of seeds to the fruit

The average apple spur bears five flowers. The central flower has the shortest stem and is usually the first to open in spring. In 1915 at the station orchard, practically all the fruits that developed came from central flowers; fruits from lateral flowers with long stems were exceptional. In 1916, on the other hand, comparatively few of the fruits had short stems. The reason for this is suggested by the following data, which were obtained just when the central flowers of the clusters were opening. The percentages are based on a consideration of all flower-bearing spurs borne on four large branches. There were over two hundred spurs.

Percentage of spurs apparently normal..... 16
Percentage of spurs with central flower abortive..... 58
Percentage of spurs with stamens and styles of central flower abnormal. 26

The abnormal stamens were undersized, malformed, and whitish; the styles also were malformed and dwarfed. The leaves of the spurs producing abnormal central flowers were somewhat wrinkled when they first opened. No disease and no insects were present. For a time it was believed that the injury might have been due to the dormant spray which was applied after the leaves appeared, but unsprayed trees along the roadside showed the same injury as did sprayed trees. These abnormalities were probably due to winter injury, presumably caused by a severe cold spell during early spring. The injury was not confined to any one variety, but all trees examined showed the same conditions. If the central flower was missing, the lateral flowers on the spur had longer stems than normal.

Counts of the number of seeds in the fruits indicated that the number was higher in 1916 than in 1915. This may have been due partly to the somewhat better weather during blooming time in 1916 than in 1915. The data in table 49 suggest that the position of the fruit on the spur may afford another explanation for this observation. It is seen from these

TABLE 49. NUMBER OF SEEDS IN SHORT-STEMMED AND IN LONG-STEMMED FRUIT

Variety	Relative length of stem	Number of fruits	Average number of seeds	Percentage with less than five seeds
Tompkins King	Short	50	5.58	32
	Long	50	6.20	8
Baldwin	Short	50	5.38	32
	Long	50	6.04	14

figures that the short-stemmed fruits, which are developed from the central flower on the spurs, can set with fewer seeds than are needed for long-stemmed fruits which are developed from lateral flowers.

Seed content and weights of long-stemmed and of short-stemmed fruits produced on the same spur

Casual observations indicated that frequently the weights of fruits borne on the same spur were not in proportion to their seed content; in many cases the fruits were of the same size altho the seed number varied, and in not a few cases the fruits with the smaller number of seeds were larger than the fruits with the greater number of seeds. Further study showed that the fruits which attained the larger size with the fewer seeds were the short-stemmed fruits. Representative data are given in table 50:

TABLE 50. SEED CONTENT AND WEIGHTS OF LONG-STEMMED AND OF SHORT-STEMMED FRUITS BORNE ON THE SAME SPUR

Spur	Long-stemmed fruits			Short-stemmed fruits		
	Length of stem (millimeters)	Number of seeds	Weight of fruit (grams)	Length of stem (millimeters)	Number of seeds	Weight of fruit (grams)
1	24	8	27.0	16	4	29
2	25	6	11.0	18	6	14
3	21	5	20.0	21	6	22
4	19	7	19.5	10	4	25
5	24	6	21.5	14	4	24
Average	22.6	6.4	19.8	15.8	4.8	22.8

As has been mentioned, the short-stemmed fruit develops from the central flower, which is the first to open in spring. These flowers would probably be pollinated before the others, and it is possible that priority of pollination may be an advantage in causing a set with fewer seeds.

The short stems frequently become clubbed, or fleshy (fig. 8). The central fruits are obviously in the most desirable position from the standpoint of sap supply. The fact that short-stemmed fruits can attain a larger size with fewer seeds than long-stemmed fruits on the same spur, lends further support to the theory that abundant sap flow is essential for fruit setting. Seeds are of value since they stimulate sap flow, but the size of the conducting tissue leading to the fruit is of considerable importance as well. This fact also emphasizes the importance of having

fruits borne under exactly the same conditions when studying the relations between weight of fruit, vigor of spur, and number of seeds. Only fruits that have developed from flowers having a similar position on their respective spurs can be compared.

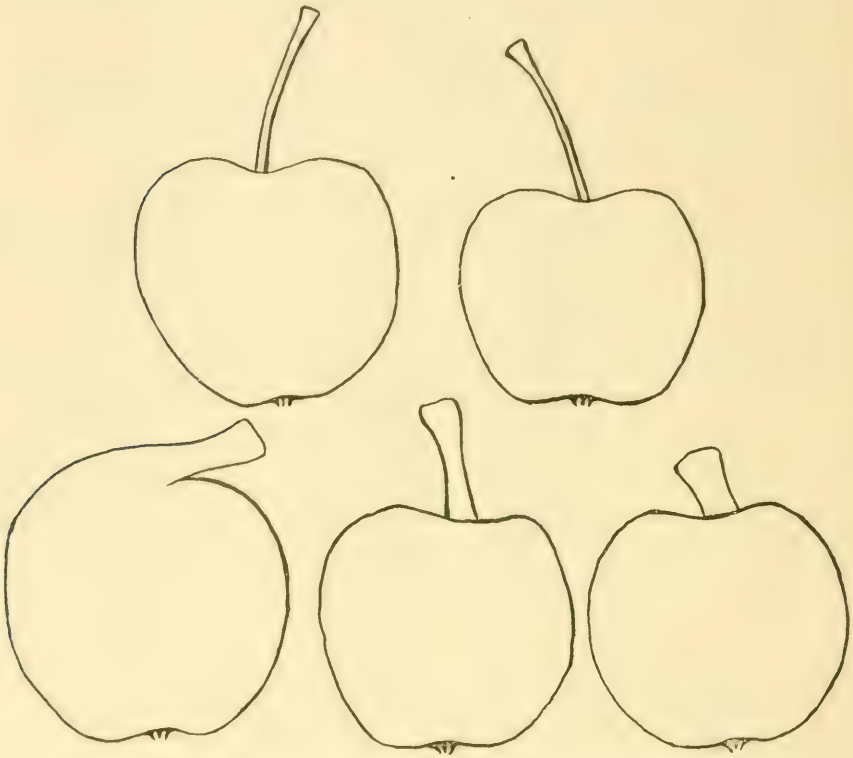

FIG. 8. FRUITS WITH LONG AND WITH SHORT STEMS

If a fruit with a long stem and one with a short stem are borne on the same spur, the former will usually be smaller than the latter even tho the former contains the greater number of seeds

Relation between number of seeds and size of fruits on spurs bearing one and on those bearing two fruits

In order to have fruits that are borne under the same conditions, only spurs bearing one fruit can be considered. If two fruits are borne on the same spur, the apples are developing under a handicap as compared with fruits borne singly. Data indicating that such conditions obtain are presented in table 51. Only the largest fruits on the two-fruited spurs were considered. The fruits were developed from lateral flowers on the spur. The variety was Tompkins King. It is seen from the table that

TABLE 51. WEIGHT OF SPUR, NUMBER OF SEEDS, AND WEIGHT OF FRUIT, ON ONE-FRUITED AND ON TWO-FRUITED SPURS

Number of fruits to the spur	Number of spurs	Average weight of spurs (grams)	Average number of seeds	Average weight of fruit (grams)
1	50	2.04	5.64	8.50
2	50	2.43	6.86	8.81

the spurs bearing one fruit produce apples nearly as heavy as the more vigorous spurs with two fruits, even tho the latter have more seeds.

Relation between aphid work and fruit development

Number of seeds in normal apples and in apples stung by aphids.— Another influence causing unequal conditions among fruits otherwise similar is that exerted by the sting of the aphid. Apples severely injured by aphids are easily recognized by their malformed condition (Parrott, Hodgkiss, and Lathrop, 1916). Such fruits will not drop even tho few or no seeds have been formed. Data regarding this point are given in table 52:

TABLE 52. AVERAGE NUMBER OF SEEDS IN NORMAL APPLES AND IN APPLES STUNG BY APHIDS

Condition of fruit	Number of fruits	Average number of seeds	Percentage having less than four seeds	Percentage having no seeds
Normal	50	6.94	22	0
Stung by aphids	100	2.93	87	20

In many cases the injury caused by aphids is not very noticeable, especially after the fruit has attained a diameter of several centimeters. There is no conspicuous malformation of the apple, and the spurs are apparently free from the pest. On close examination, however, many fruits apparently normal show the effects of aphid work. Such fruits are frequently found on weak spurs in spite of a low seed value. The stimulation resulting from the attacks of the aphid may be held accountable for such apparent discrepancies.

Water-core as affected by aphid work and water supply.—An observation regarding another influence of aphid work may be recorded at this time, since it shows that the aphid actually does influence the physiological

activities of the fruit. In the early summer of 1916, water-core was noticeable on a number of apples, especially Fall Pippin and Tompkins King. All the water-cored apples from several trees were closely examined, and in every case observed such fruits had been stung by aphids. Not all the fruits injured by the lice were water-cored, but water-cored apples that had not been stung could not be found at that time.

That water-core may, however, result from other conditions besides aphid work is shown by the following observations: During the early summer of 1915, when the fruits were about three centimeters in diameter, a number of slender branches heavily laden with apples and leaves were cut from a tree and taken to the laboratory. The cut ends of the branches were placed in beakers containing water. Many of the fruits were removed, weighed, and cut open that same evening; none of these were water-logged. The next day all the apples from several different branches showed a water-cored condition. On the following day some fruits were again examined, all of which were found to be normal. Similar observations were subsequently made on twigs brought into the laboratory primarily for this purpose.

These facts can be accounted for by the following probable explanation: The ends of the freshly cut twigs permitted the free passage of water into the branch. Transpiration during the night was reduced to a minimum, which resulted in the accumulation of water in the fruit, thereby producing the water-logged condition. After some time the ends of the twigs became clogged, due to bacterial development, and as a result water entered less freely. The leaves transpired water more rapidly than it could be supplied thru the cut end of the twigs. This produced conditions favoring incipient drying, and hence the leaves began to withdraw water from the fruit. After the withdrawal of water had been going on for a time, the fruit regained its normal condition.

The water-cored condition observed in connection with aphid work cannot be changed by detaching the spur and allowing the leaves to withdraw the water. The leaves on detached spurs with aphid-stung fruit that was water-cored, dried up in all cases, while the fruit itself remained firm. Do apples injured by lice develop a greater sap concentration than they normally possess? Unfortunately no determinations were made regarding this question.

EXPERIMENTS CONCERNING THE ABSCISS-LAYER

The shedding of flowers and immature fruits is brought about by the formation of an abscise-layer similar to that which precedes leaf fall

(Pfeffer, 1904). The formation of such a layer was induced by the following means: (1) removing the fruit and leaving varying lengths of stem; (2) coating the fruit with vaseline; and (3) submitting the fruit to humid atmospheric conditions. The effects of these various treatments are given below.

The observations recorded suggest that the formation of the abscisslayer is associated with the inhibition of sap movement. So long as the sap passes into the fruit, as it does under normal conditions, or away from it as is the case when the leaves draw the watery sap from the fruit, the layer is not formed; but when the movement of sap ceases while the spur is still active, as it does when the fruit is removed from the stem or when transpiration is checked by coating the fruit with vaseline or by exposing the fruit and the spur to humid conditions, the abscisslayer is produced which brings about the shedding of the fruit or the stem.

Effect of removing fruit and leaving varying lengths of stem

A number of Maiden Blush fruits ranging from one to one and one-half centimeters in diameter were cut from the stems in such a way that the stem in each case remained attached to the spur. The length of the stems remaining after the removal of the fruits varied. In some cases the fruit was removed and the entire stem was allowed to remain on the spur; in other cases the stem was shortened to half its original length. The first experiment was performed on June 8, 1915. Six days later the short stems readily snapped from the spurs when touched and the long stems adhered somewhat firmly, while stems that had fruits did not come off when touched. Two days later the long stems from which the fruits had been removed fell naturally. Repeated experiments gave similar results. Removal of the fruit from the stem induced the formation of the abscisslayer which resulted in the shedding of the stem. The shorter the stem, the more quickly, apparently, was this layer formed.

Effect of coating fruit with vaseline

In connection with studies concerning aphid work, the entire fruit, stem and all, was coated with vaseline. All fruits so treated fell within a week, while uncoated apples remained attached. Subsequent experiments regarding the influence of coating the fruit with vaseline gave similar results. The same effect was obtained by coating the fruit with grafting wax. The treated apples were apparently normal in all respects. The effects of coating would be to inhibit transpiration and exchange of gases.

Effect of slow and of rapid drying of leaves on detached spurs with uncoated fruit and on detached spurs with vaseline-coated fruit.—Spurs with leaves and fruits were taken from the orchard and put in the laboratory. About half of the fruits were coated with vaseline, while the others were left untreated. Some spurs with the fruits coated and some with uncoated fruits were exposed in the laboratory with the cut ends in water; others of each lot were exposed in the same place but without having access to water.

After eight days the leaves on the spurs with their cut ends in water were green and turgid. The vaseline-coated fruits had all fallen from these spurs, while the uncoated fruits remained attached. In both cases the fruits were fully turgid. The leaves on spurs not having access to water were dried up and the fruits were shriveled, but both the vaseline-coated and the normal fruits remained attached.

Effect of a saturated and of a dry atmosphere on abscission of fruit on detached spurs

A number of spurs with leaves and fruits were brought into the laboratory and placed in a heavy paper sack, after which they were thoroly moistened by immersing them in water and then allowing the water to drain off thru perforations in the bag. They were given the same treatment every day for a week. Another lot of spurs was obtained at the same time, but they were accidentally overlooked when the others were moistened. At the end of the week, the spurs in the bag that had been moistened every day had lost all their fruit; the leaves were turgid and green, and remained attached to the spurs. The spurs that had not been moistened had lost all their leaves, which were yellow and crisp, but the fruit remained attached to the spur. The fruits in the humid atmosphere of the moistened bag remained firm, while those in the dry bag had shriveled. Similar observations were subsequently made.

SUMMARY

The facts and observations contained in the foregoing pages may be summarized as follows:

1. From two-fifths to four-fifths of the total number of flowers are lost during the early drop.

2. In some varieties practically all flower-bearing spurs set fruit after the first drop; in others almost half of the spurs fail to develop fruits.

3. The proportion of spurs that set fruit after the first drop varies considerably on different trees of the same variety and on different limbs of the same tree.

4. Only three to seven per cent of the total number of flowers finally develop into fruits.

5. If comparatively few flowers begin to develop fruits, the June drop will be small; if a large number of flowers begin development, the June drop will be heavy.

6. From one-sixth to one-third of the flower-bearing spurs finally set fruit.

7. The proportion of spurs that hold fruit after the June drop varies in different trees of the same variety and on different limbs of the same tree. These variations are not due entirely to the location of the limb or to the angle at which it grows.

8. A larger proportion of spurs set fruit on limbs that have produced a relatively light bloom than on limbs that have produced a full bloom.

9. Spurs on limbs with large leaves are more likely to set fruit than spurs on limbs with small leaves.

10. During 1915 there was no consistent difference in fruitfulness between the spurs arising from 1913 wood and those arising from older wood. Comparatively few spurs arising from lateral buds on 1914 wood set fruit in 1915. The shorter the terminal growth during 1914, the greater was the tendency for lateral buds to set fruit in 1915.

11. The spurs occurring near the end of a season's growth, or just before a zone of weak buds, are the most likely to set fruit. As a rule, the spurs in the terminal half of a given season's growth set more abundantly than spurs in the basal part.

12. Spurs that lose all flowers and fruits during the first drop average fewer flowers to the spur than those that hold fruit after the June drop.

13. Spurs producing many flowers are more likely to set fruit than those that produce a small number of flowers.

14. A higher proportion of the flowers produced on spurs with many flowers set fruit, than is the case with spurs producing few flowers.

15. Spurs making more than one centimeter of growth during the preceding season have a greater tendency to set fruit than those that make less than one centimeter of growth.

16. Spurs that finally set fruit are heavier than those that lose all their flowers and fruits. Those that hold fruit until the June drop are heavier than those that lose their flowers during the first drop.

17. Spurs bearing two fruits weigh more than those bearing only one fruit.

18. A larger proportion of strong spurs set two fruits to the spur than is the case with weak spurs.

19. Spurs which produce many flowers are heavier than spurs which are taken from the same limb but which produce few flowers.

20. Spurs arising from buds that are terminal on a spur growth of more than one centimeter have a greater average weight than spurs from buds borne at the end of a shorter growth.

21. The cylinders of conducting tissue have a greater diameter in the heavy spurs than in the light spurs.

22. The average weight of spurs on limbs that produce few flower-bearing spurs is greater than for spurs produced on limbs with a full bloom. Spurs with a given diameter on the former limbs weigh more than spurs with the same diameter from the limbs with a full bloom.

23. The water supply is a factor in increasing the size of leaves. More water passes to vigorous buds than to weak buds.

24. Frequently the spurs that set fruit make a vigorous lateral growth. Limbs that set fruit on a high proportion of spurs often produce the largest amount of lateral growth from flower-bearing spurs.

25. Limbs receiving a diminished supply of sap produce fewer fruits to a hundred spurs than limbs receiving a normal or an excessive supply of sap. The small spurs as well as the large ones are benefited by an increased amount of sap.

26. Vigorous spurs from which all the leaves are removed before the flower buds open are not so fruitful as similar spurs that are not defoliated. Vigorous spurs that have all but two leaves removed, set approximately as well as normal spurs, which usually have from seven to ten bud leaves. The proportion of spurs setting more than one fruit is three times as great in the case of the check spurs as in the defoliated lot.

27. Spurs inclosed in white translucent sacks are more fruitful than those inclosed in brown opaque sacks.

28. The apples that fall in the early stages of their development have fewer seeds, on the average, than the apples that remain on the tree; but many fruits remaining on the tree have few seeds, and many fruits that drop have a high seed content.

29. In general, the weight of the fruit is proportional to the number of seeds in the fruit. The vigor of the spur on which the fruit is borne, and the size of the embryos in the seeds contained in the apple, also play a part in determining the weight of the fruit. The term *seed value* emphasizes the quality of the seeds. This quality is manifested by the ability of the individual seeds to increase the weight of the fruit, and it is associated with the size of the embryo contained in the seed. The quality may be the result of cross-fertilization.

30. Spurs bearing fruit with a low seed value are heavier on the average than spurs produced on the same limb but bearing fruits with a high seed value.

31. Leaves on detached spurs that bear fruit remain turgid for some time, since they can draw water from the fruit. Apples with many seeds lose less water than those with few seeds.

32. Sap from fruit with few seeds depresses the freezing point less than does sap from many-seeded fruits.

33. Unsymmetrical fruits resulting from imperfect fertilization are more frequent in fruit that has dropped than in fruit that remains on the tree.

34. Short-stemmed fruits, which are developed from central flowers, have fewer seeds on the average than do long-stemmed fruits.

35. Fruits with short stems usually attain a greater weight than fruits with long stems borne on the same spur, even tho the latter may contain more seeds.

36. Fruits borne singly on vigorous spurs may attain a weight as great as that of the larger apples from spurs bearing two fruits, even tho the latter may have a greater seed content.

37. The average number of seeds in a normal apple is greater than in fruit that has been stung by aphids. Apples attacked by aphids remain attached to the tree even tho no seeds are formed.

38. Fruits stung by aphids may develop a water-cored condition. Such a condition is also caused by over-abundant water supply.

39. Removal of the fruit from its stem induces the formation of an absciss-layer between the stem and the spur, which results in the shedding of the stem. The shorter the stem, the more quickly is the absciss-layer formed.

40. Fruits coated with vaseline or grafting wax fall after one week.

41. Detached fruiting spurs kept in a receptacle with a saturated atmosphere lose their apples after several days; similar spurs kept in a dry atmosphere retain their fruit.

42. Vaseline-coated fruits on spurs with their stems standing in water fall after eight days; fruits similarly treated on spurs not having access to water remain attached to the spurs. Untreated fruits on spurs standing in water also remain hanging.

GENERAL DISCUSSION

The results presented in the foregoing pages emphasize the importance of vigor, more especially the vigor of the individual spur, as a factor in fruit setting. As compared to weak spurs, the previous season's growth of vigorous spurs is longer, the new spur growth is heavier, the leaves are larger and more numerous, there are more flowers to the spur, the diameter of the conducting tissue is greater, and the weight of the lateral spur growth is greater.

The vigorous spurs seem to favor fruit setting because they can supply the developing fruits with an abundance of water and food. Seeds appear to be valuable because they supplement the forces that bring sap to the fruit. Strong seeds are of primary importance for the setting of fruit on relatively weak spurs; they are of lesser importance for the setting of fruit on strong spurs.

The number of strong seeds is dependent on effective fertilization, which in turn presupposes cross-pollination. Even tho the grower may plant several varieties of the same fruit which bloom during the same time, nevertheless cross-pollination is frequently prevented by unfavorable weather during blooming time. Man has little control over the weather. On the other hand, man may influence the vigor of the tree by cultural methods. Trees in sod, for example, are usually less vigorous than trees in a tilled orchard. The latter, as a rule, produce heavier crops of fruit.

In Mr. Cornwall's orchard, at Pultneyville, New York, the Baldwin trees were heavily laden with fruit in 1915. Other Baldwin trees around Pultneyville produced relatively light crops that year. The weather at blooming time in that locality was cold, cloudy, windy, and rainy—very unfavorable for cross-pollination. The trees on the Cornwall farm were in the best of condition. The owner plowed his orchard very early in the spring and put in a cover crop the latter part of June and early in July. This treatment would be conducive to rapid, vigorous growth of the spurs early in spring, and early planting of the cover crop would tend to check further elongation and permit of abundant food storage in and near the terminal buds. According to the observations recorded herein, such conditions would favor fruit setting without the aid of many strong seeds, and hence a fairly good crop might be expected even tho the weather during blooming time were unfavorable. Plowing in late fall under some conditions may prove more advantageous than very late spring plowing, so far as setting of fruit is concerned.

The application of a quick-acting nitrogenous fertilizer, such as sodium nitrate, early in spring may have a decided effect in stimulating early and rapid spur growth that would be likely to set fruit the following year. Some evidence for this suggestion is contained in the paper by Lewis and Allen (1915), received by the writer while the present report was in the course of preparation.

Much has been said regarding so-called self-sterility of certain varieties which under a given set of conditions seem to be benefited by cross-pollination. As has been observed by Waite (1894) and others, the degree of self-sterility varies from year to year and in different trees of the same variety under different cultural treatments and in different localities. From the standpoint of the species, a condition of self-sterility

is desirable because only cross-pollinated flowers would mature fruits and seeds on such trees. Cross-pollinated seeds would tend to produce more variable seedlings, and it might be expected that desirable variations, from the species' standpoint, would occur.

From man's standpoint, however, self-fertile varieties, or those that can mature fruit without strong seeds, are more desirable because there are more chances of a crop if the necessity of cross-pollination can be eliminated. So far as is known in the case of the apple, the presence of seeds has no effect on the quality of the fruit. Seeds affect the size, but size can be produced without the aid of seeds. It is conceivable that a tree bearing a heavy crop of many-seeded fruits is being devitalized to a far greater extent than another tree of the same variety bearing a crop of fruits equally heavy but having relatively few seeds. This hypothesis presupposes that the production of seeds requires more energy and food than the mere production of the flesh of the fruit.

The problem, then, it seems, is to find cultural treatments that are favorable to self-fertility. This is by no means a simple problem. One should not expect, for example, that the soil treatment which proves favorable for one or more varieties will prove favorable for all. Any treatments, however, that produce relatively long spur growth and provide for an abundance of stored food, and any treatments that influence the vigor of the individual spur, may be expected to be favorable for the development of blossoms into fruit without cross-pollination. Unfavorable climatic conditions may be involved in the self-sterility of a given variety; if such is the case, nothing can be done but to make the best provisions for cross-pollination.

The observations and experiments recorded in the preceding pages justify the tentative conclusion that unfavorable conditions of nutrition and water supply are among the basic factors which cause the normal drop of flowers and partially developed fruits of the apple. All factors that have a direct or an indirect influence on nutrition and water supply of the flower and the fruit, such as pollination, weather, cultivation, and the like, are of importance. Fruit development, however, is possible without cross-pollination and even under relatively unfavorable weather conditions, so long as the young fruit has an abundant supply of water and of readily available food.

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